# A Visit to Soviet Science

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First Edition



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# THE RACE INTO COSMOS

Gone are the times when the writer's imagination sped ahead of life, into strange utopias. The physicists and engineers have taken the initiative and are converting the dreams of the utopians into reality.

A few weeks before the launching of the sun's tenth planet, Professor Leonid Sedov told me in Moscow that within the next twenty years manned spaceships would fly to Mars and Venus; and Professor Alexander Mikhailov, in Pulkovo, joked that, given the proper timing of their arrival, landing parties on the moon might heat their hot dogs with the gas of crater Alphons. Where is the borderline between fantasy and reality? The saber-rattling of the atom generals has become ridiculous, a hollow clatter from the scrap heap of history.

The first thick snow of winter had fallen before Moscow's skyscraper university. The cloak room attendants in the ground floor marble lobby were checking galoshes and fur caps, and the students in the elevators wore pink cheeks. The man I was going to see probably knew that a few weeks hence an attempt would be made to break out of the earth's field of gravitation, so as to reach the moon and beyond.

Snow clouds drifting past the windows of Professor Sedov's office blocked the view on the city. Giant potted plants, an old vintage radio, a green baize-covered table, dark woods gave the room a lived-in feeling. The Professor, head of the Soviet Academy of Sciences' Committee on Astronautics, sat at his desk, extremely well groomed, his gray hair precisely parted, every inch a man of the world; and to elicit from him answers on sputnik plans was like pulling teeth. Sometimes his eyes narrowed as if hiding a smile.

All the more surprising was his sudden commitment on the timetable for space trips to Mars and Venus; the twenty years figure he gave was obviously calculated with months to spare. Not long before, in the spring of 1958, his colleague Professor Fyodorov had made essentially the same prediction, but he had presented the schedule in hazier terms—"In our lifetime," he had said to me, "yours and mine."

Something had happened between my conversations with the two Soviet space experts, something to permit Professor Sedov almost to pinpoint the perspective of man's conquest of the universe. It wasn't hard to guess. Sputnik Three had gone up, and its findings, at least partially, had been analyzed.

The course and behavior of the first cosmic rocket, our tenth planet, must have confirmed the views of the Soviet scientists. The prophesies are no longer restricted to private conversations. Professor Blagonravov now said it in print, in *Komsomolskaya Pravda*, "One of you reading this will one day walk along the rims of a crater of the moon, or uncover the centuries-old secret of the canals of Mars, or penetrate the eternal clouds covering the surface of Venus. . . ."

And truly, the scientific tasks assigned to the Soviet cosmic rocket read like a catalogue of what the future space skipper will have to know before setting out on his trips. Here's the list:

Ascertain the magnetic field of the moon; find the intensity and the variations of intensity of cosmic rays outside the magnetic field of the earth; register the photons in cosmic radiation; discover the radioactivity of the moon, if any; analyze the distribution of heavy nuclei in cosmic radiation; probe the gas components of interplanetary matter; study corpuscular solar radiation; test for meteoric particles in space.

It seems incredible that only a little more than a year should have passed since Oct. 4, 1957, when the first Sputnik sent its triumphant *beep-beep* into the ether. In fifteen months: From 83.6 to 1,472 kilograms, from 900 kilometers into interplanetary space, from first cosmic speed to second, from a tiny knock at the gates of heaven to a breakthrough into the universe.

But not only in man's relation to the space surrounding him have things changed during this brief time. Another very tangible change has come about right here on our globe, in the relation of a great many people to the spiritual values of socialism. If one sputnik was an uncomfortable jolt, three sputniks and a man-made planet were a pattern. And the Americans, by turning a scientific program into a race with military overtones, did everything to make public opinion politically conscious. Today, hardly anyone anywhere will deny that Soviet science and its progress are closely linked to the social order from which they spring.

When Professor Evgenij Konstantinovich Fyodorov told me that we'd be seeing space travel within our lifetime, I naturally asked him how old he was. It turned out we both were born shortly before World War One. Life expectancy being what it is, I could figure the approximate date of the first flotilla of manned space rockets taking off from "somewhere in the European part of the Soviet Union."

Fyodorov, head of the Soviet Committee for the Geophysical Year and thus the more or less official sputnik spokesman, actually is neither

a rocket expert nor a physicist. He is a meteorologist, a weather man, and at the slightest provocation he will go off into his beloved clouds, especially thunder clouds, which he is trying to turn into rain before they can turn into hail. When you see a good-looking, immaculately dressed man pouring a few kilograms of table salt into a cloud, the likelihood is that it will be Professor Fyodorov playing with the weather. He refuses to be called a rain maker, though. "We can transform clouds," he says, "make them disappear over airports, for instance, but not always can we turn them into economically useful amounts of rain. That's because a cloud is not a thing, but a process. . . . We've got to put the cloud to work, so to speak, make it attract more water, though we haven't solved that problem yet. . . ."

The Americans are afraid that the Soviet weather men will solve it. After Sputnik One, the *Bulletin of American Meteorological Societies* wrote, there was no doubt that the Russians could solve any scientific problem, and the *Bulletin* shuddered at the thought that the Russians might monopolize all the good weather at the expense of the USA.

As is, the sputniks had been a big enough shock. All along I'd been thinking that they were one of the best kept secrets of history, that this was why the beep-beep of Sputnik One had hit everybody with such force.

But in Leningrad I was told by Professor Mikhailov, director of Pulkovo Observatory, that they had been informed of the alleged secret at least half a year ahead of time — and not only had it been known to the scientists at Pulkovo but also to people at dozens of observation stations in the People's Democracies! When you distribute several hundred specially built telescopes with instructions for the observation of a satellite, the secret is bound to leak out.

In fact, it had been no secret to start with. In June, 1957, three months before Sputnik One, Professor Fyodorov had announced the Soviet satellite program at a press conference in Moscow. The reports must have reached Washington, because a few days later President Eisenhower told his rocket people to get busy and shoot something into space.

Why, then, the amazement over Sputnik One? Why, then, had the world press been aghast and NATO been agog? Why had all of them acted as if Soviet science had snuck up from behind to put one over on the unsuspecting capitalist public?

Very simple: because the Soviet Union was the Cinderella in the case. The surprise of practically everybody in the West was exactly what the two rich sisters must have experienced when the Prince put the little glass slipper on Cinderella's pretty foot. They hadn't believed

the muzhiks could do it. They had believed the image they had made for themselves of the Soviet people and Soviet science. It was the inevitable result of years of self-delusion. They had postured so often as top man and permanent winner that they had come to believe their own publicity. And so overwhelming had been the weight of this build-up that the Soviet scientists, too, had accepted it at face value!

"Yes," confirmed Professor Fyodorov, "we also assumed that the Americans would be the first to get a satellite into space."

"But why? Why?"

"Because for two years they'd done nothing but talk about it."

When I spoke for the first time to Professor Alexander Mikhailov in Pulkovo, the break-up of Sputnik Two was expected at any hour. The gentle old man, one of the great contemporary astronomers, admitted to feeling a little sad about it. He showed me photographs they had taken, and his thin finger followed the thread of white which the sputnik had woven between the stars. So much painstaking patience and devotion to the great job, so much thought, so much hope hurtled through outer space along with that piece of metal which was about to be burned by its touch with the atmosphere.

With a quick movement of his hand the Professor waved sentiment out the window and turned to what then seemed like dim future and what now has become the reality of our day or part of the immediate agenda – a rocket to reach the moon, perhaps to circle it and photograph its far side and televise to us what human eyes have never seen; perhaps even to land on this, the first way station into the universe. There were things about which he badly wanted information: the ultraviolet light of the galaxies, for instance; or the temperature on the moon's concealed side. We know so little and the world is so big. . . .

Later in Moscow, Professor Fyodorov sat across the table from me, a pot of tea and glasses and a bowl of chocolates between us; it was the time of the interregnum between Sputnik Two and Sputnik Three. I tried to draw him out on when Number Three would be along and what it would be like and which jobs it would be called upon to do.

"You know," I said, "the score is three to two, at the moment, in favor of the Americans. Theirs may be dwarfed by yours – but theirs are up, and with dumb people like me it's what's up that counts, and for better or for worse, the sputniks have a political side."

The Professor behaved as though he was unaware of it. He calmly gave me a lesson on what science considers important. It isn't the number of rockets you fire at the sky—it's what's contained in their nose cones. It's the payload that matters, the number and variety of instruments which are taken aloft for the research the scientists on earth want them to perform, plus the necessary sources of energy, the governing equipment, the transmitters. Naturally, the bigger your sputnik, the heavier its payload, the richer its scientific results. He spoke of flying laboratories, and he told me of the step-by-step program of geophysical and astronautical research which the Soviet space satellites are carrying out.

"You wouldn't by chance start one for the First of May?" I inquired, less placid than he. "I'll still be in the Soviet Union on that date and would be very glad to accept an invitation to see it zoom up..."

"We're in no rush," he said.

"Will Number Three be heavier than its predecessors? With a couple of monkeys, maybe?"

"There will be a number of sputniks—some smaller, some larger, some with animals, some without, depending on what they are to achieve. But one thing is certain: to get a satellite into space with a good and heavy payload, you have to use a combination of ICBM's or intercontinental ballistic missiles. With intermediate-range rockets or a single ICBM you're too limited."

"You're training dogs for space travel," I said. "Have you trained any humans lately?"

"For that," he answered thoughtfully, "we would first have to solve the problem of safe return from space. We're working on it."

"Will you get there first, or the Americans?"

"Why do you want to know?"

"Because I think that the issue of atomic war or peace depends among other things on the socialist system holding its lead in sputniks..."

Astronomy, Professor Mikhailov had told me, was the most international of sciences because the same stars shone over all of us. And Professor Fyodorov had stated that meteorology was one science the warmongers could never use because the winds blow everywhere.

Was there a chance of a horrible nightmare coming true, of some gang of half-crazed imperialists ruling mankind from some spaceship hovering over the earth and threatening disobedient peoples with atomic annihilation?

Professor Fyodorov conceded the possibility of a crash program by which the United States might catch up with Soviet rocket and satellite progress. But there is a dialectical contradiction in the thing which, to my mind, makes it unlikely. And it was, of all people, the Nazi Wernher von Braun, America's rocket ace, who put his finger on it when recently he said before the U. S. Congress's newly created Space Committee: "The United States can meet the challenge of outer space exploration only if it will discontinue our unfortunate practice of supporting only such research and development as serves immediate military objectives."

Here lies the crux of the matter. Contrary to the old saying war is not the father of all things; peaceful labor is. At the foundation of all scientific progress lies basic research, lies man's relentless unencumbered quest into the secrets of nature. And no scientist can work properly with a general constantly looking over his shoulder and asking: Can I use this thing to shoot with?

The sputniks, after all, are not the result of one crash program in one or two hand-picked branches of science. They can only be, and are, the product of a team of scientists who come from many different sciences, all of which have attained a development high enough for man's reach into the universe.

I asked Professor Sedov what sort of team this was and was there really a team spirit or did you also find those most human of human failings – ambition, rivalry, back-biting.

I shall never forget the Professor's answer. He began by describing the enormous, almost unbearable stress of the days before a sputnik launching, the nights without sleep when in his mind each man went over and over the thousand-and-one items, each one of which would have to function without flaw if the venture was to succeed. "You can believe me," he said, "it's a spirit not only of team or collective – but of comradeship and friendship, of one man helping the other, one group helping the other. Without that, the whole thing wouldn't work."

If you prefer the language of politics, you might call it the spirit of socialism. It exists. It is, of course, not part of everybody's make-up in the socialist countries, but it exists in a number of people sufficiently large to account for the jump forward we are witnessing.

That it happened so dramatically and just at the point when man was readying himself to solve the riddle of matter and to step outside the limits of his planet, at the threshold of a new age – this might have been a quirk of fate.

But I don't believe in such quirks. I believe that there is a

link between the revolution that was started by the guns of the cruiser Aurora and the revolution ushered in by the beep-beep of Sputnik One – the new revolution whose regiments are recruited from the sixty thousand young scientists and engineers coming annually from the universities and technical colleges of the world's first socialist country.

## One Million Times Faster Than Thought

Some people may tut-tut the idea of the new revolution, but they wouldn't be the first people in the middle of a revolution who never noticed it until it was over.

I am talking of the kind of revolution, with the kind of revolutionary consequences, which the German economist, philosopher, and rebel Karl Marx described in that famous Chapter 13 of his famous book *Das Kapital:* the industrial revolution. I think we're in the first stages of a new, and greater, industrial revolution; and as did the industrial revolution of the 18th and 19th centuries, this one will change the lives of all of us and of our children and children's children to the very depths of our existence.

Marx speaks in Chapter 13 of the "restraints of human strength." Until machines, and machines to drive machines, came into being, production was limited by what man and his tools, or a combination of many men with their tools, could do. The machine, however, which is many tools at once, gave man a hundred or even a thousand hands instead of the two he formerly had; machines that drove machines, by steam or gasoline or electricity, gave man a thousand or even a hundred thousand times the power he formerly commanded. The machines broke through the "restraints of human strength."

We are now breaking through the restraints of human *thought.* And, for the second time and on a much higher level, we are extending the limits of human strength by leaving behind us the sources of power contained in molecular processes and by tapping the enormous energies of the nuclei. Whole collectives of Prometheuses are setting out to conquer the fires of the sun.

If this isn't a revolution, what *is?*

At first meeting, Professor Sergey Alexeyevich Lebedev appears to be a painfully shy man. He sits stiffly upright and doesn't quite seem to know where to rest his hands. I doubt very much that he ever thought of himself as a Prometheus or any other kind of demigod; but he has

already increased the speed of human thought to ten thousand times what it was, and he has even bigger plans.

"Why so fast?" he was asked. "If the computing machine you're building does a thousand operations a second, you will have solved all the mathematical problems in the world within two or three weeks . . ."

Professor Lebedev, head of the Soviet Academy of Sciences' Institute of Precision Mechanics and Computing Technique, permits himself a slight chuckle.

"What do you call your baby?" I inquired.

"Bystrodjestvuyuchtchaya Elektronnaya Skhotnaya Mashina."

"Please?"

"Highspeed Electronic Computing Machine."

"Ah."

"For short, BESM."

"And it does a thousand operations a second?"

"No, ten thousand. You see, the baby has grown."

"Oh."

"Not in size, just in capability. In fact, as it became faster it shrank in size."

"Professor Lebedev?"

"Yes?"

"*Are* there any mathematical problems left in the Soviet Union?"

Again the chuckle. "It seems the faster the machine works and the more computing machines we build, the more customers we get with ever-increasing mathematical problems. Our baby calculates, for instance, the orbit of the sputniks, helps out in atomic research, figures out problems in aerodynamics, hydrodynamics, turbine building, radar, crystallography, chemistry, pure mathematics, and for relaxation it translates. We've even taught it to sing and play chess."

"Good chess?"

"Mediocre. It can think only three or four moves ahead."

"What about novels? Can you teach it to write novels?"

"The machine can do anything requiring mechanical thinking."

"I see," said I. "It depends on the quality of the book."

Actually, this is the nub of the question raised by the birth of the new high-speed thinking machines. Will they, can they ever supplant the thinking of man? And what and how far can they be made to think?

The imagination of people, of poets and writers especially, has always been fired by the idea of the machine that can think, the machine which takes the drudgery and sweat out of human life. As long as the work of slaves or serfs or proletarians degrades them to machines

or adjuncts of machines, the thought of a machine stepping in to relieve them will lie close to the human heart. The men who died building the pyramids must have had that dream, and those who slaved to pave the roads of the Roman emperors. From the gnomes and Heinzelmännchen who took the work off the hands of the medieval serf and his harassed wife, through the Golem fashioned of clay but brought to life by the learned rabbi's sacred formula, to Karel Capek's Universal Robots in his play "R.U.R." extends one thread, one longing.

One can also find in all of these stories the same fear bringing about the same twist: the revolt of the machine against man, its creator. The oppressed people who invented the story transferred their own desire for rebellion into the heart of the machine that could think; themselves robots, the people felt that the robot-machine, too, must be rebelliously inclined. The gnomes upset the house when their conditions aren't met; the Golem goes on a rampage; the Universal Robots destroy humanity: the class struggle is simply expressed in terms of a struggle of machine against man.

And though we tend to clothe the problem in a joke, there is at bottom a deep unrest when we ask about our relationship to the thinking machine, which undoubtedly will develop with giant strides to take more and more work off our hands and minds. Man wasn't born to exploit man; exploiters always feel uneasy in some corner of their minds; and a machine that plays chess with you and translates into foreign languages can appear too damned human for comfort.

Let me first set at ease the minds of those who never saw an electronic computing machine. It doesn't look like a human. It looks a little like a huge cupboard whose front panels are filled with clusters of electron tubes busily blinking away and whose rear is garnished with a maze of many-colored wires and tiny relays that make as little sense to the layman as would the nerve cords of the human body.

At least, that's what the first digital computing machine I saw looked like to me, and that was a little old slow-poke which shuffled along at a mere one hundred operations a second in the Institute of Physics of the Academy of Sciences. Grouped around it, apparently in idle chatter, were some young men and women.

On being introduced to them I learned that the curly-headed young man with the serious expression was Boris Marshuk, head of the Institute's Department of Research into and Planning of Computing Machines, and all of 26 years old; that the fellow at his elbow, certainly not much older than he, was the assistant constructor of the machine, Benjamin Antonov; that the pretty little blonde behind

them, engineer Evgenja Ivanovna Lebed, had graduated in 1957 and was learning the computing machine trade in preparation to run such a machine on her own; that the girl with the sparkling brown eyes and the lively face, Natalya Yerichova, was a physicist currently interested in which part of the molecule rotated in what direction around which other part, and was present as a "customer" who just hung around while the machine solved the problem she had brought for it; and that the machine had the brand name "Ural" and the serial number 008, was a year and a half old, was being industrially produced in the USSR but would soon be supplanted by a new model using mostly semiconductors instead of electron tubes and no bigger than a night table.

"How come you're all that young?" I asked.

Marshuk said, "Because we're a young science!"

"And a young country," added the molecule girl.

"Tell me how it works," I said.

"The machine? Very simply," said Antonov. He should know; he was responsible for all that wiring, I think. "Now, let's take this equation . . ."

He wrote down an equation the like of which they forgot to teach me in school. I took away his piece of paper and wrote down: 3 times 5. Then I said, "Please, explain how your machine does *that!*"

"But you can do 3 times 5 in your head!" he cried.

"I know. That's why I want you to explain to me how your machine does it. At least I can check up whether what comes out is anywhere near fifteen."

I must say he honestly tried. I'm sure he could have explained his equation and the machine's solving it beautifully. But 3 times 5 beat him. It was too simple.

They all felt bad about it and attempted to apologize, while the machine indifferently went on solving the molecule girl's homework. "It would have taken me eight hours," the girl said, "doing it with my own brain. I used to have to do it, too."

The little blonde brought her a long slip of paper of the sort that comes out of the cash register of the grocery.

"Now the machine does it in two minutes," said the molecule girl, and to the blonde, "Thank you very much."

"Was it very complicated?" I asked.

"Very," said the molecule girl. "I told you, eight hours."

"Could this machine maybe also write novels?" I asked.

"Why not?" said Antonov, to make up for his 3 times 5 fiasco. "If it solves those equations..."

"Comrades!" Marshuk, as head of the department, asserted his authority. "If the Comrade Foreign Writer can furnish us the laws inherent in his story and style—"

"That's true!" said the molecule girl, pocketing her results. "But the point is, the machine novels will always be ersatz, so to speak. Take music. Take Tchaikovsky. Yes, the machine can write like Tchaikovsky—but only *like* him. It couldn't write like Tchaikovsky without there having been a Tchaikovsky who first wrote like Tchaikovsky. You understand?"

She looked very inspired, and I was a little sorry I wasn't one of those molecules she was dealing with.

"Remember Eugene Onegin?" She sang, "Ta-taa—ta-*te*—ta-*ta*—ta-*tee*-ta!"

"I remember."

"Now, we would have to find out what laws underlie this particular sequence of tones and their rhythm and emphases, and then express these laws mathematically and punch them on this piece of film and feed them into the electronic memory of the machine, and then it would start writing variations of Ta-taa—ta-*te*—ta-*ta*—ta-*tee*-ta.... But first you need Tchaikovsky, and then some other human brain that would take apart Tchaikovsky until you have the basic components of his music...

"The machine may compute and think a hundred or ten thousand or a million times as fast as man, but it can never think creatively. Its memory, which is all that it knows, is given it by man; its line of action is prescribed it by man. It may be a wonderful crutch for man, but there isn't a crutch in the world that can walk by itself."

The search for the inherent law, whether it be of aerodynamics, language, or Tchaikovsky, is and remains man's noble task.

Professor Lebedev grew voluble. "If the essence of language were just words the job would be simple for the computing machine. All we'd have to do is to number the words in a Russian-English dictionary and feed the numbers into the electronic memory and then feed the English text into the input device to have the machine fire away with the appropriate Russian words. But that would be dictionary language, just nominative and infinitive. Nobody speaks Russian that way."

"I do," I said.

"Well," he said, "the machine has to do better. It has got to come up with a grammatically correct version. So, when it gets a sentence to translate it must not only, with each word, run through

all the words in its electronic dictionary-memory but it must also analyze the sentence, parse it, consider cases, verb forms, tenses, irregularities, and what have you. Therefore, man must first formulate for the machine the laws of the languages it is to translate and reduce these laws to numbers which the machine can digest. If your law isn't correct, or if you failed to formulate it correctly, the machine will give you a garbled sentence. We have a whole staff of linguists and mathematicians working together...

"However, once the preparatory work is done by man, the machine will work quickly and efficiently. We're now trying to get it to read directly from the printed page."

"The printed —?"

"Page. Yes. Do away with the tape. Tape is cumbersome, you know."

"Isn't it getting a little too smart, Professor, this machine of yours?"

"Oh, no. Man is a very clumsy creator. An earthworm, I suppose, has more of a brain than we can ever give the machine."

"An earthworm can't translate."

"But it gets along without being programmed by man."

Professor Lebedev's Bystrodjestvuyuchtchaya Elektronnaya Skhotnaya Mashina stands in a longish room in a building on Moscow's Lenin Prospect. All around it the new Moscow with its pattern of eight-story apartment blocks along superwide highways is mushrooming. But in here you hear only the staccato of what appears to be a distant machine gun as the printing mechanism puts the numerals of the finished calculations on an unending strip of paper.

Huge closets filled with electron tubes dwarf the few people who come near. Yet there is ample space: an empty steel frame shows that originally another of the closets had stood here.

"I told you," says the Professor, "the baby shrank as it grew. What's missing there is the old memory of the machine: forty electron tubes, each the size of a large water carafe. Want to see the new one?"

The new memory, with ten times the efficiency of the old one, could fit in about one-sixth of the space its predecessor took. Professor Lebedev opens the small cupboard. There are six frames, each holding a dense lattice of wire, and at each crossing of wire you see a tiny blob of metal, a ferrite, the Professor says, which can hold a tiny magnetic field and which represents, so to speak, one cell of the artificial brain. But this is only the everyday, immediate-use memory which is emptied and stored again as the job requires; in addition,

the machine can fall back on a couple of more permanent memories, one on magnetic tape, the other on a magnetic drum which, covered over like the ordinary mortal's subconscious, stands behind the closet with the photoelectric intake device.

"This machine," says the Professor modestly, "can do sixty-four different operations at the rate of ten thousand operations a second. It is the fastest in Europe."

"Just in Europe?"

"The Americans have one that does fifteen thousand."

"And your Bystrodjestvuyuchtchaya wouldn't manage that with a little added tinkering?"

Professor Lebedev shrugs. "We consider we've developed this model far enough. We shall now progress to a new model with a target of one hundred thousand to two hundred thousand operations a second."

"Molodyets!" I said, which is Russian and which the machine would translate in a flash as "Hot stuff!" or "Nice going!" or, if it felt very British that day, as "Smashing!"

"Thank you very kindly," said the Professor. "However, this is nothing final. We are projecting a computing machine with an efficiency between one and ten million operations a second and of a size which would permit it to be taken along on a trip into outer space... No, I can't tell you exactly when we'll have it ready, but in our science, work develops at a fairly fast rate."

Professor Lebedev nods pleasantly.

"Don't forget, we entered the field of high-speed electronic computing machines fairly recently. When this institute opened its doors, in 1950, we had no scientific cadres with experience in this special sphere; we had to learn as we went along, and we learned on this, what you call, baby."

"One million operations a second," I said, not immediately grasping the full significance of the statement.

"We'll need them, too," said Professor Lebedev.

It might be well to keep in mind this factor: *One Million.* To be able to think one million times as fast as was possible a few years ago means not just faster thinking — it means a different kind of thinking. It means the change of quantity into a new quality. It means that, freed from the limitations of the brain's relatively slow work, we can tackle tasks that formerly were outside our reach. It means travel into space, where only rapid calculation of greatest exactitude can save the returning spaceship from missing that speck in the universe

which we inhabit; it means a new mathematics for which a great many problems considered insoluble until now no longer exist; it means extending the scope of every science to undreamed-of horizons.

It means that man, liberated from the routine tasks with which he has had to burden his brain, will be able to settle back to do some quiet creative thinking. It means the jump from bookkeeper to planner, from technician to inventor, from mechanical to original thinker — a jump as big as that from primitive pottery-making to conveyor-belt production.

For the digital computing machine of Professor Lebedev is only one — though perhaps the most complex — of a great number of thinking machines, small or big, highspeed or super-highspeed, that are ready to step in and measure and weigh and calculate and regulate and adjust where man used to poke around with his gauge and scale and pencil stub and his poor, overburdened brain. The governing machine has come into being, more exact and more faithful than any human operator, never tiring, leaving to man the really interesting, creative part of the work: the setting of the task, the programming.

It is only now that man truly can become the master of his labor.

Under socialism, that is.

## The Realm of the Fantastic

We are entering the realm of the fantastic, which, however, is becoming tomorrow's reality.

Science has set itself the task of creating systems that work without man and perform jobs which up to yesterday were reserved to beings with a higher nervous system. There rides along in Sputnik Three a little machine which is called a governor. It takes the place of man, who cannot yet be sent into space. It automatically controls and governs the work of all the scientific instruments and measuring devices in the satellite, switching them on or off at certain intervals. It tells the sputnik's radio transmitter when to start transmitting and when to stop. It even broadcasts exact time signals, which are needed down on earth to adjust the results of the sputnik's scientific measurements to astronomic time and geographic coordinates. It needs no sleep. It does what it's supposed to do without fuss and bother, and it doesn't have to be fed chocolate milk shakes through the hermetically sealed cabin like that American lieutenant who tried playing sputnik on the ground.

I've had an argument with some of the younger scientists I met

in Moscow on when the quantity of new technical developments would mount to the point where it changed into a new quality. Being an optimist, I saw that point in the very near future. But a young physicist named Alexander Bartchukov stopped me. "We can talk of a new quality," he said, "when we begin applying physics to biology and vice versa."

"What do you mean?" I asked.

He reached up into the air in a characteristic gesture and withdrew his hand as if he had plucked a beautiful fruit out of the nothing. "When we get milk out of the air instead of from the cow," he prophesied, "we'll have that new quality."

For the moment, Bartchukov's statement fazed me by the never-never perspectives it set. But as I saw more of Soviet physical research, the analogy between the human brain controlling and directing the functions of the body and the electronic governor controlling and directing the functions of one or several machines grew on me. I was not amazed, therefore, when Professor Trapeznikov of the Academy's Institute of Automation and Telemechanics told me that he hoped to learn something for his electronic governing machines from the biologists' studies of the governing system of the human body.

"Could you begin by explaining the principle of the governing machine?" I asked him.

It was a lucky hit; because Professor Vladimir Alexandrovich Trapeznikov, cool and detached behind his desk, and most impressive with his white, wavy hair and his ruddy complexion, turned out to have one of those systematic minds which break down everything into (a) and (b) and (c), thereby enabling you to grasp quickly what might have taken you weeks to understand. Besides, he seemed to me to represent the thinking of Soviet scientists on the subject.

"We are entering the epoch of automation," he said. "The possibilities are boundless.

"For automation we will have to solve two problems:

"(1) to design, construct, arrange in line, and link up machines that are sufficiently mechanized;

"(2) to institute automatic governing so as to regulate and control these machines.

"Point (1) is, strictly speaking, mechanization and becomes automation only in conjunction with point (2)."

He looked at me to make certain he hadn't lost me on the way. I nodded, to reassure him.

"Point (2)," he went on, "offers the following three problems:

"(a) automatic choice of program — you have to find the best,

the most practical, the most economical way of carrying through your process, and you have to find it automatically;

"(b) automatic control — you have to know whether your process develops correctly or not;

"(c) automatic adjustment — if your process deviates from the desired standard it must be automatically corrected."

"Well," I said, "it seems a pretty big slice you've cut off for yourself."

I guess he had waited for something like that before he sprang his surprise. In a most casual tone he said, "From the scientific point of view, problems (b), automatic control, and (c), automatic adjustment, may be considered as solved, with the exception, perhaps, of some minor items which still need to be taken care of."

He didn't have to look at me to know that he had floored me properly.

"As to problem (a), this is being tackled now, and with recent developments in computing techniques it, too, will be solved. During the last year, the main task of our institute was the design and development of a self-adjusting system which does its own programming. All man does is to give the machine the necessary and desired criteria of what he wants to have done. From then on, it's in the hands of the machine. The machine figures out the best regimen, the best program, the best solution; it passes on the order to the machines it governs; it controls them and adjusts them if necessary."

I wanted to inquire whether it swept the floor, too, but Professor Trapeznikov was continuing, "This is a new approach to automation and one of the newest directions in which our research develops. To give you some examples: power stations. The machine will take over for the dispatcher, and on the basis of given conditions will figure out the most favorable regimen for the whole grid — which turbines are to produce at what time and which stations are to transfer what blocks of power to which places and for how long. Or a rolling mill — all you do is tell the machine what diameter steel you want and the maximum deviation permitted, and the machine will calculate the details of the operation and set the rest of the machinery. Or in the chemical industry — the machine will determine the best mixture of components, will check performance during the process, and when necessary, adjust mixture, temperature, and so on, to keep the product's desired quality.

"In short, the machine will do for man quickly and efficiently a great number of things which man had to do himself and which he did slowly, sloppily, and often with considerable economic loss."

"Yes," I said.

"Do you have any doubts?"

"No."

"But perhaps there is some point you don't understand?"

He had explained everything so beautifully that any school child should have caught on, and I hated to disappoint him. "You mean to say," I began carefully, "that you take one of Professor Lebedev's chess-playing giants and put him in your power stations, your rolling mills, your chemical plants . . ."

Professor Trapeznikov permitted himself a slight sigh. "You do not shoot sparrows with rocket artillery," he said patiently. "For simple jobs use simple devices. They don't even necessarily have to be electronic. We have some very practical pneumatic computers that regulate extreme values; we have analogy computing machines of various sizes and shapes; we have —"

As it turned out, he didn't have all the lovely pieces he wanted to show. Some of his nicest exhibits, performing the neatest tricks, were in Brussels at the World's Fair, and I had to be satisfied with items which had not yet received the final touch, gadgets whose wiring still showed, appliances still in the process of being tested.

I pick at random: A remote control governor capable of regulating and running simultaneously 36 objects — 36 oil wells, 36 irrigation sluice gates, 36 pressure valves, 36 underground mines converting coal into gas, and so on. It's no bigger than a small upright piano. You set it to the levels you want maintained; the machine does everything else. You can also change your arrangement, long distance, by throwing a few small switches.

This thing still works by wire and electromagnetic relays on the spot. But they've already developed a much smaller contrivance, the size of a large suitcase, which does the same job without wire connection to the objects controlled, and which in addition counts and reports to you the delivery of your gas mines, your oil wells, your irrigation canals.

I can still see the tall, gangly laboratory assistant showing me a metal case no bigger than a cigar box with a long antenna attached. "Ah," I said, happy to have found an old acquaintance, "a walkie-talkie!"

"It's a radio transmitter, too" — he marked off a small corner of the case — "but the transmitting mechanism is only in this part of it. The rest of it is something else. Watch!"

At the other side of the room stood a green-painted toy crane that I had admired when I came in; it was that true to detail. The assistant

flicked a couple of switches on his little metal case: the crane began to move. It turned, then dipped, lowered its fangs, opened them, picked up a load of toy rocks, lifted them, turned again, and neatly deposited them at my feet.

"Magic?"

"Telemechanics," he said.

The king of thinking machines, though, is the computer.

The "Ural" and Professor Lebedev's Bystrodjestvuyuchtchaya had been digital computers reducing every mathematical task, every figure, to its barest essentials: the numerals 0 and 1, converting these into electrical impulses, and again building up from there to achieve the desired result.

But most of the programming and governing of machines is a routine job which can be stripped down to a few mathematical equations. An analogy computer, of which there are a great many models, will be good enough to apply the actual data to the ever-recurring equations and to figure out the most favorable solutions for our technical problems. This computer doesn't work with 0 and 1; it works by analogy, by re-creating electrically the precise conditions that apply mechanically to the machine you want to program and govern. It becomes, so to speak, the electrical "model" of your lathe, your turbine, your automatic line, your power grid; and it shows by a lovely green curve on its oscillograph, or by translation of the curve into numbers, or by direct regulatory action what it thinks should be done.

At Professor Trapeznikov's I saw a beautiful little one, portable, no bigger than a normal table radio. You plug it into the nearest outlet in the wall and it will start solving equations, either linear or nonlinear, but only one or two at a time. If you want to have twelve to fourteen nonlinear equations solved simultaneously, which may become necessary in the control and adjusting of an automatic line of machines, you have to go to the institute of Professor Trapeznikov's friendly competitor, the great Blagonravov, and have young Professor Bychovsky show you model MNM, the size of the small hope chest our grandmothers took with them from home when they got married to our grandfathers.

Professor Mikhail Lazarovich Bychovsky, Doctor of Technical Science, is all of 39, looks 29, and is working on the design of what he calls a "self-organizing system," a machine which, he says, would operate in some sense like the human body. It will adjust itself quite by itself to the conditions under which it has to perform as well as to the tasks it is given. In arctic cold, in desert heat, underground or

on mountain tops, slowly or at great speed, the machine is to be able to produce radio parts one day, maybe parts of an automobile engine the next, and another day parts of radar equipment — and all this change-over without a touch of the human hand. In addition, it is automatically to replace any of its own parts which happen to break.

No — Professor Bychovsky is an absolutely sound, well-balanced specimen of Soviet man. Nor does he write poetry, he assures me. And he hopes to have solved the main portion of the scientific problems connected with his "self-organizing system" in two years.

## The Sage of Leningrad

The old man who had been sitting patiently on the platform got up and walked to the lectern. The weight of his years had somewhat rounded his shoulders, and he straightened as he looked over his audience: professors and students, research men, a sprinkling of army officers, a few journalists.

Outside the huge windows of the hall, the gray blue of the Leningrad night reflected itself in the sluggish waters of the Neva; across the river the spire of the Admiralty gleamed golden; and inside here the pictures, the old-fashioned chairs, the columns, the rich hue of the walls spoke of the continuity of life: of handing on to those who come after you what you have gleaned from nature's reluctantly divulged secrets, of spreading the seed of knowledge and making the toil of man a little easier.

As he glanced down at the faces that were turned to him expectantly there was a slight tremble of his white mustache, as if it were hiding the gentlest of smiles, and his eyes twinkled with humor and affection. He was going to speak of his friend Max Planck, who had developed the quantum theory and had found the constant *h* equaling $6.62 \times 10^{-27}$ erg second, and who would have celebrated his one-hundredth birthday a few days hence if, some years ago, death had not entered the poor attic room in the small German town of Göttingen and said, "Come along, Professor. The laws of physics apply to everybody."

The old man glancing down from the lectern in the Leningrad auditorium of the Academy of Sciences had known them all: Planck and Einstein and Roentgen and others whose names were immortalized in laws and equations and rays and measurements and who had formed a worldwide fraternity of a most special kind in which you understood one another by a few internationally recognized symbols — Planck's *h*,

for instance, or Einstein's *E* and *m* and *c*. There was no Yoffe law, he thought, but there were, all over the length and breadth of the great Soviet land, men he had helped to form and institutions he had helped to found. He had helped the best and most promising of his pupils to strike out on their own; they now were professors at the universities or headed great institutes and research laboratories in Leningrad or Moscow, in Dubna or in the south of the country, in the Urals or in Siberia, where a new center of science was rising close to the new centers of industry.

Abram Fyodorovich Yoffe spoke without notes. He knew the subject of his lecture expertly: life. "As a young man," he said, "Max Planck was in doubt whether to become a musician or a physicist. So Planck went to some older friend of his and asked for advice and got it. What do you want to become a physicist for, his friend said, when all the problems of physics have long ago been solved..."

The white mustache twitched again. The problems of Newton's physics — yes, Newton, whom LaGrange had praised as the happiest of scientists because he had succeeded in giving the one and only, ultimate, rounded-out, satisfactory picture of the world. But, since Newton, physics had tackled entirely new dimensions, and he, Yoffe, had tried to solve some of the new problems, especially after 1918 when the young Soviet government, despite all its troubles, had let him organize the first of his research institutions, the Physical-Technical Institute in Leningrad.

But if you solved one riddle in physics, two more presented themselves. Why, not even on the point of his beloved semiconductors were matters as clear as you might desire. The quantum theory of semiconductors, for instance, did not agree with some of the findings which had been arrived at experimentally across the river, at his Institute for Semiconductors. Why was it so? And where was the theoretical interpretation of the new phenomena?

The old man's voice went on, slightly hoarse, honoring the great Planck. In a few days Abram Fyodorovich Yoffe would pack a small suitcase and travel to Berlin where the fraternity of physicists was to meet for Planck's one hundredth birthday, where the men of science would extol the discoverer of the factor *h*, would exchange the latest results of thought and research, and would protest, some loud, some not so loud, against the misuse of their thought and their research by some of the governments of this world. In a few weeks another sputnik, the third, would rise, carrying within its shiny body two thousand, maybe three thousand, of his semiconductors.

The tiny glass tube, not much thicker than a match stick and maybe one quarter its length, containing a sliver of germanium or something similar, with a few thin, protruding wires, has become a familiar item in any laboratory, shop, or plant dealing with electronics.

Unlike large-size sputniks, semiconductors are no Soviet monopoly. Nor are they a Soviet invention. Semiconducting materials were known by the middle of the last century, but their rapid development and many-purpose use are recent phenomena which occurred almost simultaneously in several of the highly industrialized countries. I think one can say that Soviet research in semiconductors keeps well abreast of international progress and is ahead in a few important applications of semiconductor elements.

It is the off-again on-again quality of the semiconductors which makes them such fantastic and useful articles. In fact you might say that together with their older and much bigger cousins, the electron tubes, they are the cells from which the mighty body of automation, with its triple features of automatic programming, automatic control, and automatic adjustment, will grow.

The way I see it semiconductors are simply materials which will conduct electricity under a specific condition – when a certain temperature has been reached, or under the stimulation of light or ultraviolet rays or radioactivity or what have you. In addition, several of these semiconductors are particularly capricious. Some will let pass only a current running from plus to minus; others vice versa.

It all has to do with the electrons in the outer shell of the atoms. If you have eight electrons in this outer shell they are happy and stay together, and the material containing these atoms with the happy electrons in the outer shell is known as an insulator; but if there are less than eight electrons, they can get the wanderlust pretty badly and stray all over the place as so-called free electrons, and if you hold your finger to that leaky plug in the wall you can get an awful shock because you're not an insulator, Mister, you're a conductor.

The whole business of semiconductors has been made even more complicated by Professor Bogolyubov's brand-new superconductor theory. I was present at the conference at which Bogolyubov, a stocky man with a shock of hair that almost covered his eyes, tried to explain his theory to the international press. He tried valiantly, but all he got from the press was a question from a gentleman who represented a Baltimore paper, "Can you tell us, Professor, what the practical application of it is?"

It seemed the Professor hadn't given much thought to this aspect;

all he had thought up was a likely explanation for why metals at temperatures near absolute zero — minus 273 degrees Celsius — start behaving so strangely and lose all resistance to electric current.... It's those electrons again. Professor Bogolyubov found that when it gets that cold the electrons become very excited, turn superfluid, and even form collectives.

This behavior of the electrons, I hear from other sources, makes the new superconductors just the right thing for highly sensitive relays and for bigger and better memories in the computing machines. Of course, it might be a little hard on the operator to work the computing machine at close to $-273°$ when even the electrons start shivering and bunch up into collectives. So, until an alloy is discovered which turns superconductive at ordinary Russian winter temperatures, Soviet technique will have to coast along with the semiconductors from Professor Yoffe's institute.

For these, Professor Yoffe counts eighteen different, widely divergent uses. Add up what they can do, these diodes, triodes, transistors, spacistors, thermistors, thermocouples, and you have a new technique: the technique of the era of automation.

And you have proportions appropriate to the new industrial revolution: to the cramped conditions aboard a space ship, to the need for compactness which economic necessity demands everywhere. A dozen electron tubes in a radio set are all right; six thousand electron tubes in a high-speed computing machine are an unwieldy mess; practically unworkable, too, since at least one of the tubes would have to go on the blink every hour on the hour. Remember the old memory of Professor Lebedev's Bystrodjestvuyuchtchaya? It was a structure approximately twelve feet high and eighteen feet long; and it worked at only one-tenth the speed of the new one, which consists of six small wire-netted frames with semiconductors, each frame three feet by three.

We're only at the beginning of semiconductor development. Emerson Radio in the U.S. advertises vest pocket radio sets running on eight transistors. But at the Institute for Semiconductors in Leningrad, Professor Vladimir Pantelejmonovich Zhusé showed me a gadget no bigger than a matchbox which will multiply and divide and, as if this weren't enough, analyze the most complex electrical currents. Perhaps I should add that the thing which actually does the computing and analyzing in Professor Zhusé's device is about the size of the nail on my little finger; by far the larger part of the matchbox is taken up by an ordinary small electromagnet creating the magnetic field in which the miracle takes place.

I've seen the pilot model of a refrigerator working with thermocouples. It looks like your ordinary refrigerator, except that its back is studded with several rows of metal fins arranged fanwise. That is all – no motor, no moving parts, no noise, no gas, no odor, no worry, no repairmen; just the fins which are warm on the outside and covered with hoarfrost on the refrigerator's inside. I've ordered one of these refrigerators. It is to be on the market next year and will cost about half the price of the present models of comparable size.

I've seen portable micro-refrigerators of various shapes and sizes that help you to transport blood or specimens or the greetings which the prize bull sends to the cows on distant kolkhozes; I've seen a microtome table freezing small bits of tissue and permitting the doctor to slice them down to the transparent thinness he needs for his microscope; I've seen an instrument which takes the splinter of skull or piece of jawbone our forebears left for us, amplifies the infinitesimal radioactivity of the carbon isotope C-12 contained in those relics, and enables anthropologists to determine the approximate date when our great-granddaddy went on his last hunt.

And I've seen some of those solar batteries that now help Sputnik Three to broadcast the results of its investigations in outer space.

"The future?" said Professor Zhusé, toying with his matchbox-sized multiplication machine. "We're scientists, not prophets."

"You could make a try at it," I said.

He laughed. Some girls were carrying bunches of flowers and branches of green through the hallway of the Institute. "We're having a pre-First of May celebration tonight," said Professor Zhusé, as if he wanted to explain this unscientific invasion of spring.

"All right," I said. "What would you tell the people on this First of May, in the year 1958?"

"What *I* would tell them? That we're here to make work a little easier for people. And that these semi conductors will help us to do it – not only in radio and electronics. They will measure and regulate for man: temperature, pressure, light, current. They will compute and calculate for him. And, perhaps most important, they will convert one form of energy into another."

He paused. Two young men came by with a red transparency that was to decorate the hall.

"Atomic power stations are old-fashioned," Professor Zhusé went on. "Their atomic heat is used to make steam, the steam drives the turbine, and it's only the turbine that produces electricity. How clumsy and expensive! And how much energy do you lose on the way? But the

day will come when we're able to convert radioactivity directly, the short way, into electric current; when the rays of the sun will drive our machines; when daylight is stored to be poured out at night; when the warmth of spring will be at our command to make a world in bloom . . ."

"Is that just your First of May speech," I smiled, "or a real possibility?"

"With semiconductors," he replied, "the impossible comes within reach, and the possible turns into reality."

## Automation Is a Two-Edged Sword

Two images are uppermost of the many that come to mind as I think of automation and its meaning.

The one is a cartoon in a recent *New Yorker* magazine. It shows a woman and a man in front of their fireplace, a married couple, obviously, both of them distinctly upper class. And while he looks as if the cigar in his mouth suddenly tasted of herring, her face displays a singular mixture of boredom and lack of understanding as she states, "I can't understand why you keep fretting, John. Automation or no automation, there will always be a Chairman of the Board."

The other is the memory of a smile I saw at the Lichatchov Automobile Plant in Moscow. The smile belonged to a worker named Valentin Kuzmich Tarapkov, a haggard-faced man whom I met at the automatic line which produces cylinder blocks. The line was impressive, forty-eight big machines standing in a sort of S-formation, each machine receiving from its neighbor to the left the heavy eight-cylinder truck engine block and passing it on to the neighbor on its right; each performing with untiring strength the precise operation it was geared for; finishing it uniformly in the same two minutes and forty-five seconds allotted to it; while all the forty-eight cylinder blocks that were simultaneously being ground, honed, bored, drilled, milled were simultaneously screaming, squeaking, groaning, yowling, and howling.

In this racket some men stood near a small control desk, talking. The cramped space available between the rows of machines had been made more cramped by a roughly carpentered table and a bench that had seen better days; on the table stood a checkerboard set up for the next game, with nuts forming the one and bolts the other team of checkers.

The haggard-faced man was introduced to me as one of those workers who had been employed in this department before it was

automated, turning out identical cylinder blocks before the machine took the entire job off his hands.

"Well," I said, "is it better now?"

And then came that smile. It looked a little like the smile you sometimes see on old icons when the painter wants to express the rapture of the saint who has glimpsed unbearable, superhuman joy.

"Don't you see?" said Tarapkov. "I'm standing here, talking with you, smoking a cigarette, and I used to have to grab these blocks with my own two hands and shove them into position and put them into the machine . . ." He spread his arms and tensed, demonstrating the size and weight of the cylinder block.

Tarapkov was forty-five when the line was installed, in 1952. At forty-five he went back to school, at company expense, and learned how to operate the new, infinitely more complicated machinery. It was an evening school, run at the plant, by the plant, for the plant's men; and while he learned he continued earning money, and now he earns more than he ever did.

"Five men," said Tarapkov, "at this section of the line now turn out as much work as thirty-two men used to produce before the line came in."

"And what happened to the other twenty-seven?"

"What twenty-seven?" he asked.

"Who formerly worked here," I said, somewhat shocked at his apparent lack of concern.

"They still work here," said Tarapkov, now with a different smile that had in it kindness toward the uninformed foreigner and hesitancy natural to explaining something which he never thought needed explanation. "Of course they still work here, in one or the other department; I don't know which, the plant is big. You can't fire a man because you put in bigger and better machines. You've got to get him work that's as good as he had or better. And there's so much work, always . . ."

I pointed to the tremendous, noise-filled hall, with its many departments, its hundreds of machines.

"And suppose," I said, "all this were automated. And everywhere, here at Lichatchov, in all of Moscow, in the whole Soviet Union, five men did the work that thirty-two used to do. What then?"

Tarapkov's eyes grew small in his grease-smeared face. He seemed to want to assess whether I meant my question or was propounding a damn-fool hypothetical case.

Then he laughed and nodded toward the ramshackle table and the homemade checker game. "We'll have a little more time to play," he

said, and suddenly sensed that he was looking into the future. "It would be nice," he said slowly. "So many things I wanted to do, always . . ."

According to the strict definitions which Professor Trapeznikov at the Institute for Automation and Telemechanics adopted, automation proper demands a minimum of automatic self-control on the part of the machine.

In practice, however, I found that the phrase "automatic line" is used even where man still checks and controls and adjusts, provided you have a line of interconnected machines that pass or "transfer," to use the correct terminology, the work piece from one to another. The cylinder block line at the Lichatchov Automobile Plant, one of the oldest of automatic lines in the rapidly developing Soviet automation, is built on the transfer principle pure and simple. The line will stop if something goes seriously wrong in one of the machines; but the machines can't test or correct themselves.

A similar transfer line, much smaller in proportion, stands at the Second Moscow Watch Factory. It produces the bodies of their Pobyeda model men's wrist watch. I want to try to describe it because it's so bright and clean and compact, and because it illustrates, I think, a whole social development.

At the left of the machine is a box with thousands of rough castings that come from the plant's casting department. A worker puts forty of them onto a metal stick and inserts them into the automatic line's storage point. From there the machine takes over. A little steel arm with a gripper at its end reaches out, picks the topmost casting out of the storage point, and transfers it to Station One of the automatic line which does the first operation on the work piece – grinding, I believe. After eight seconds, an arm from Station Two swings over to take the work piece away from Station One and feed it into Two, and so on, every eight seconds, through all the ten stations of the automatic line, until the body of the Pobyeda watch, ground to precise size, polished on either side, and with all the little holes that go into a watch body drilled in, falls exhausted out of Station Ten into the waiting receptacle.

When you stand five or ten minutes and look at these mechanical arms moving, gripping, turning, inserting every eight seconds with relentless precision, you get a funny feeling. You're glad that it's a machine doing this mechanical work and not you.

And then comes the dramatic surprise as you turn around and see in the same hall thirty or forty girls sitting behind thirty or forty conventional machines and doing on the models of other watches the work you saw the automatic line do on the Pobyeda. And you see again

the mechanical motion of arms, but now the arms are flesh-colored and belong to human beings, to workers.

No, these are not workers in a capitalist plant. They are not hurried to the point of great fatigue; they have more social rights than any union in any capitalist country could ever get for its members. They are clean and well-fed and happy. It's simply that they still have to do the kind of mechanical work that today should be below thinking human beings. If the machine can do it, man no longer needs to do it. And at the machine-building shop of the Second Moscow Watch Factory, where the first automatic line in the world's watch industry was built, they're already constructing new, improved, and bigger automatic machinery to take over from the girls and permit them to apply themselves to more stimulating work.

For automation is no chance development – neither under capitalism nor under socialism. It came when the long, long process of mechanization, simplification, and organization in the mass industries had reached the point where work no longer needed the worker's thought or skill and where the worker became an adjunct, almost a part of the machine, himself a robot, an automaton.

From there to the complete replacement of the worker by the machine, to automation of production, is only a short step.

It is at this point that automation begins to show its two-edged character, and the difference between capitalist and socialist automation becomes apparent.

Technically, very little difference exists between automation here and there. It isn't my job to nice-nelly or, as the Russians say, to "lacquer" things; nor, I'm happy to say, are the Soviet scientists and engineers I spoke to in the habit of spreading illusions. In Moscow, Engineer A. E. Prokopovich prefaced his remarks to me by stating, "As an engineer and specialist, it would be ridiculous for me to say that everything they do in the United States is bad and everything we do in the Soviet Union is perfect. Automation develops very fast in both parts of the world; over there as well as here engineers have to start from existing plant, the technical level is about the same, and automatic lines are built more or less according to the same principles in both socialist and capitalist countries."

And Prokopovich isn't just anybody. He is Chief Engineer of the Experimental Research Institute of Metal-cutting Machines, the famous "ENIMS," which develops the Soviet Union's heavy automatic lines and produces their pilot models at its large Stanko-Konstruktsija Plant. Furthermore, he said it to me just after he had shown me the

latest of their lines under construction — a giant affair consisting of thirteen large machines which will automatically turn out rotors for electromotors, with the thirteenth machine possessing an electronic brain by means of which the rotor is finally balanced according to precise specifications.

You can't help being impressed by the steel hands that receive the shaft as it travels down the line, insert it into the lathe, and remove it again after a pair of metal fingers within the lathe have convinced themselves that the piece has been worked just so, with a tolerance of only a few thousandths of a millimeter. You can't help being impressed when you see a machine assemble the typical fanlike collar of the rotor to the shaft and, finally, see another machine with a brain of its own weigh the whole thing and give some order inaudible to you, following which tiny drills take out tiny bits of steel from this or the other end of the shaft, until the machine is sure of the perfection of its job.

"Sometimes we're proud," said Prokopovich, "when Western engineers use one or the other of our ideas. It shows that we're ahead in this particular field. And sometimes we take an idea of theirs and develop it . . ."

I liked Prokopovich immensely. He had been a worker before he studied engineering and philosophy. He had a musician's sensitive face and hands, but from the way he talked to men you saw that he knew how to make decisions.

"Fifteen or twenty years ago," he added thoughtfully, "it was all one way. It was *we* who took from them. And I tell you, the rate of development would have been much faster, much more in our favor, but for the war . . ." His voice trailed off. "A beautiful plant we had built in Byelorussia, all brand-new and shiny, and I was the director. For exactly three weeks. Then the Germans came; and when we returned, nothing was left."

He was still mourning that plant as if it were his child dead in infancy. And it probably meant just that to him.

"This rate of development," I reminded him after a pause, "how do you explain it? And is it the only difference between the two kinds of automation, West and East?"

"It's a difference in principle." He leaned forward. "I don't know if I'll succeed, but I'll try to explain it. It's a difference in the approach to mechanization and automation. Naturally, both of us, the capitalists and we, want automation because it increases productivity. But to them higher productivity means increased profits, and that's what they look at, and they weigh the possibilities of profits in automation against the outlay of capital which automation requires. And where they don't

see that they can amortize quickly and start piling in the profits, they won't automate."

"And you?" I asked.

"To us higher productivity of labor means higher living standards. We plan for that. We have the long view and the longer breadth. But automation, to us, holds more than an increase in labor productivity. We want to find such techniques as will make the labor of man interesting and stimulating, so that man's labor will be in harmony with man's spirit in a Communist society; we want to do away with labor that's a physical strain and a mental bore. We want man to use his brain, not his muscle. And for that we'll sometimes even sacrifice an immediate advantage of productivity. You play chess?"

"A little," I said. "I'm a great loser."

"But you know at least," he said, "that there are two schools of thought in chess. The one says every single move must bring you an immediate gain; the other believes that you can concede something sometimes so as to gain a decisive advantage. The latter," he added slowly, "is the Russian school."

"All right," I said, "that's chess."

"You will no doubt find a greater number of automatic lines at Ford's in Detroit," he said, "than at Lichatchov in Moscow. We will invest, though, in automation developments that might pay us back only in fifteen or twenty years' time. We will even sacrifice immediate productivity so as to make labor physically easier and more of a challenge to the human mind. We're convinced that through this we'll have a long-run increase of productivity that's incomparably higher. Here is the real reason that sometimes and in some field we suddenly make a great leap ahead and, to their great amazement, quickly surpass our capitalist colleagues. And *sometimes* will become *always,* and *some field* will become *everywhere.*"

Among my favorite clippings is an item from the economics page of a recent issue of the *New York Herald Tribune.* It is captioned "One-man Factory," and it reads:

> "The Marma-Langror bleaching plant near Gavle, Sweden, which has a capacity of 70,000 tons of sulphite pulp annually, is now so highly automated that one man watching an 80-foot panel with 400 gauges is the only human participating in the process. The 70 phases of the production process are operated by 200 mechanical devices controlled by 30 automatic governors. The control panel is diagramed to mirror the actual layout of the processing machinery and is connected to it by 35 miles of electric wiring."

This little item is the complement to the *New Yorker* cartoon of the worried executive and his puzzled wife. Because there is, naturally, in the Marma-Langror one-man factory one other man besides the harassed guy watching those 400 gauges at his 80-foot panel: the Chairman of the Board.

And the Chairman *is* troubled. He senses that something in this automation and his one-man factory threatens him.

Whether the capitalists like it or not, Karl Marx's idea that they feed, clothe, and house themselves – and not badly – from the surplus value they get out of their workers is based on fact. How much surplus value can a capitalist get out of one worker supervising an automated factory? Certainly not enough to maintain himself and his family in the style to which past surplus value has accustomed them. I believe the capitalist would prefer going out of business to sacrificing his standard of living to the beauties of automation.

I showed the *Herald Tribune* item to Prokopovich and asked him what advice he would give to help this capitalist with his solitary worker out of the contradictions of automation.

He said the capitalists wouldn't be interested in his advice.

I said I wasn't too worried about the capitalists. As I remembered it, Marx mentioned something about the rate of profit being based on *socially necessary* labor; so that the Chairman of the Board of the One-man Factory near Gavle would be able to make super-duper profits on his single worker – until the other sulphite pulp manufacturers got wise to the trick and converted to one-man production, too. That's when the real predicament would start. Price structures in sulphite pulp would collapse and the market go kaput – and it wasn't just this one industry. Automation was a general thing, deepening the general antagonistic contradictions of capitalism.

"I have a feeling," said Prokopovich, "that those antagonistic contradictions will ultimately slow down the progress of automation under capitalism, while we continue going ahead because we don't suffer from them."

"It must have been two years ago, maybe three," I said, "that the Chairman of the Board of General Motors took the President of the United Automobile Workers Union of America, Mr. Walter Reuther, through one of the General Motors plants. It was just prior to the annual wage talks. The executive showed the union official some of the newest automatic machinery and commented: 'Mr. Reuther, you are going to have difficulty collecting union dues from all these machines.' The union president, however, had his answer: 'Mr. Chair-

man of the Board, you are going to have more difficulty selling automobiles to them!' "

"They both seem to be having difficulty now," remarked Prokopovich, "Mr. Reuther and General Motors; anyhow, it's the workers who suffer. Perhaps I can give you another union opinion. A recent resolution of British Auto Workers says: In order to make the full benefits of automation available to workers and to all people, the social system will have to be changed."

Under which social system you automate – that is the crux of the question, automation being a two-edged sword that can cut both ways. It can cut the time and the effort of the job that has to be done and make man's life happier and richer – under socialism. And it can cut a man's whole job away from under his feet and make his life a harrowing, humiliating misery – under capitalism.

West of the river Elbe, and especially in the United States, a worker thinking of automation automatically thinks of unemployment. In the West automation and unemployment are like Siamese twins, born through the terrible wedlock of technical progress and an outdated form of economy. It will take an operation to separate the twins so that automation can become a blessing in the West, too.

The link-up of unemployment and automation is nothing new, though it has come dramatically to the fore with the recession that is currently fanning out from the United States. This link-up has been apparent since the early fifties. In the comparatively minor slump of 1953 the Pittsburgh mills alone laid off 40,000 steel workers. In 1955 the industry was back to peak production, but of the 40,000 only 14,000 were returned to their jobs. "The remaining 26,000," as the *London Times* of Aug. 30, 1955, put it, "have become permanently unemployed, displaced by automation."

Displaced by automation.... A job which the automatic machine takes over, man never gets back. He becomes *redundant*, a lovely, soft-sounding word the capitalists have picked from the dictionary in order to avoid saying to the worker: You're of no use to us anymore, you're finished, you're through, you're out.

I know of no figures on the present-day recession in the United States that indicate which percentage of unemployment is due to the general economic causes of a cyclical crisis and which to automation. The two go hand in hand, a grisly pair taking the worker's little house and his television set and his refrigerator and, in the end, the bread out of his children's mouths.

The apologists for capitalism say that people displaced by auto-

mation will find jobs elsewhere in capitalist economy and that men are needed to build the automatic machines and to run them. Sure, *some* men are needed; but never as many as were fired. In fact, the capitalists would never start automating if they didn't see a saving in manpower, a saving in wages which is greater than the cost of automation. What other inducement would make the bosses go to such expense and trouble?

That's automation in the free enterprise system.

But precisely this will help to hasten the end of this sort of free enterprise. As the journal of the Detroit Tool and Die Makers wrote: "We hate to mention it, yet there is the possibility that the free-enterprisers with their automation are free-enterprising free enterprise out of business."

And under socialism?

Certainly: A job which the automatic machine takes over, man never gets back; this rule applies under socialism just as well. However, it works out quite differently in an ever-expanding planned economy. In such an economy you bless the machine that takes the drudgery off your hands, because it has freed you to start on that better, more interesting, more rewarding job which is already waiting for you.

"A while ago," I said to Prokopovich, "you mentioned that in this country and under socialism you do not suffer from the antagonistic contradictions which give such a headache to the capitalists. Is there, perhaps, another kind of contradiction bothering you?"

"We have a proverb in Russian," he said. "On the map everything looks smooth, but the ground is full of ditches."

"And the ditches are full of contradictions?"

"Nonantagonistic ones. Contradictions which we can solve with a little patience and a lot of thought."

"Such as?"

"Such as in engineering and organization. Industry has old, old traditions of structure: machine plus man, one man to a machine, and the controls corresponding to this conception. The new techniques demand an entirely new organization of the plant, with new kinds of control. We have to learn how to jump over our own shadow.

"Or: contradictions in engineering technique. The easiest way to build an automatic line is to build it around one specific piece of work you want to turn out, from one specific material, always to the same specifications. Modern development, however, means constant change. You can't throw out a whole automatic line or even parts of it because the work piece has to be changed, but neither can you permit

the automatic line to hold back your change and progress. You must develop an automatic line that you can change along with the changes your product requires. You must develop the *universal* automatic line!"

"Can you do it?"

"I think we have found the principal approach to it," said Prokopovich, "and in some cases we have licked the problem. Our automatic line for gears will produce them in any diameter from 80 mm. to 300 mm., with any number of teeth and any tooth profile you like; and the changeover from one model gear to another takes no more than two hours."

"Comparatively speaking," I said, "aren't these rather minor contradictions?"

"Not to the engineer."

"But to the sociologist..."

"All right," he said, "I was coming to it. There is the difficulty with the workers."

"The workers?"

"The new workers. The new workers we must educate and create for our automatic lines. The automatic machine replaces unskilled or semi-skilled men, and it needs men with what approximates engineering skills. You've seen some of those lines. We started building them in 1936, and we have since produced automatic lines for cylinder blocks, pistons, piston rings, shafts, ball bearings, gear wheels, flanged shafts, conic gears; and some of those lines with automatic assembly. These are complicated combines, and they grow more complicated as we go along.

"There was a superstition that automation is simple: Push a button, and off it goes; anybody can do it. In one plant they told the fireman to operate the automatic line. The line lasted three minutes, then it stopped, and they said that automation was no good. We had to convince them and teach them. But where do you get enough men to run these automated machines and lines and plants? Right now we improvise. We'll take a trained engineer and put him to work on the line; or we take a particularly capable worker and train him to work it. But we need masses of an entirely new type of worker whose qualifications lie somewhere between the skilled man and the engineer, but closer to the engineer. We need the worker-engineer or engineer-worker or whichever you want to call him..."

"The worker of Communism."

"Yes, the worker of Communism."

He gestured shortly. This new worker seemed to be dear to his heart.

"And the creation of this worker is a process of not just three or five years but of twenty or possibly forty. We must plan for him. We must organize a system of education for him. Think of the wide range of knowledge he needs. We've made the beginning with the universal ten-year school, with the technical college courses in our big plants, with technicums and institutes and correspondence schools and universities all over. We graduate sixty thousand engineers annually. We will graduate many more. We will become a nation of students, young and old, studying while we work and studying while we play, to master the new technique and the new forces, to master nature."

## The Struggle for Power

Think of a war-ravaged country fighting to preserve its revolution, to defeat the troops of its former ruling class, to drive back the armies of intervention. Think of a dark, chilly day in November, 1920, with starvation rampant and armored trains rumbling over shaky track and men fighting and bleeding and dying on a half-dozen fronts....

On this day a letter came to Lenin's desk reading as follows:

> "On November 14 electric lighting will be switched on in the village of Kashino. We humbly request your presence on this occasion to share the joy we feel at the sight of electric light in the cottages of peasants who under the tsar did not even dare to dream of this. Please, do come."

And Lenin went. As the generator of the tiny power station started turning he said, "You see, your village of Kashino is producing electricity. That is only one village. It is important to us that the whole country be flooded with light. The Soviet Government is now working out a plan for electrification. Electricity will till and fertilize the soil for us, will carry us..."

This plan has become known to history as the GOELRO plan, the plan for the electrification of Russia, and at the time of its proclamation the world thought it stuff and nonsense. H. G. Wells, to whom Lenin spoke of it, wrote, "...in a vast flat land of forests and illiterate peasants, with no water power, with no technical skill available, and with trade and industry at the last gasp? ... Lenin, who like a good orthodox Marxist denounces all Utopians, has succumbed at last to a Utopia, the Utopia of the electricians..."

And he called Lenin a dreamer.

But if you can get millions of men to dream the same dream, this dream becomes reality. The GOELRO plan foresaw the building of thirty power stations in fifteen years, with a total capacity of one and a half million kilowatts. The plan was fulfilled in less than ten years. The capacity of today's Soviet Union is many times the electric power that Lenin dreamed of.

This is more easily written than it was done. What the Soviets did in their electric power production is something akin to Baron Munchausen's feat of pulling himself up by his own bootstraps. They started with less than nothing; what had the tsars and the white guard generals left to them? Then, in the midst of their driving work, another world war came and smashed the first flower of their effort.

Dneprostroi – what pride it had been, what joy, to listen to the purr of the turbines. They had paid for it with a Dnieper of sweat: do you think those foreign specialists took ordinary rubles? Dollars were the currency they demanded, cold cash, greenbacks; and more, many more, than they ever could have gotten for the same sort of work in the United States. Those foreign machine-builders were businessmen, hard-headed; they knew when they had someone cornered, and they squeezed a pile of gold out of a people that lived on black bread and not too much of that. And then to see Dneprostroi blown up, the sweep of the dam and its beauty destroyed, the turbines and their purr! . . .

Thereby hangs a tale. I want to tell it because, like a milestone, it denotes a measure of way traveled on a very hard road. It also speaks of the initiative which, according to western sources, ceases to exist in a socialist form of economy.

Even before the Soviet armies sweeping back from Stalingrad had reached the Dnieper, preparations were made for the rebuilding of the power station; and the hard-headed businessmen in the West who were now the allies of the Soviet Union were requested to consider the construction of new generators to replace the destroyed ones, and how much would it cost? In dollars, of course.

It was then, in 1944, that eight engineers of the Leningrad Metal Works – and Leningrad, too, was just beginning to revive after its siege – wrote a letter to the Secretary General of the Soviet Communist Party in which they said that not only could they build the turbines and the generators for the new Dneprostroi but that they could build them at less cost and with a better performance than imported ones.

I have seen a carbon copy of that letter. It was cheap paper, yellowed at the edges, and it was beginning to fall apart at the creases.

Like its original it carries the signatures of the eight engineers, and among them is the name of the man who took it out of his filing cabinet and showed it to me: N. N. Kovalyov.

He is now a professor and chief constructor at the Leningrad Metal Works. "They got our letter," he said, "and they took us up on it, and we did it. That's how it is that in today's Dneprostroi you find three American and six Soviet generators. And ours perform better; and if something goes wrong with an American turbine we use Soviet replacement parts."

The Leningrad Metal Works lie at the Neva where the river turns drab and is no longer fringed by palaces with white columns and pink cornices and golden roofs. It's an old plant, as industry goes, dating back to prerevolutionary times, and it has made electric power history.

Here I met men like Georgij Bugrov, foreman of the turbine assembly hall, who is part of that history and is still helping to make it. Bugrov, who years ago argued with Ordzhonikidze for money to build this hall; who stood by when the factory's first turbine was turned out, a midget turbine that five men could lift and load with their bare hands. Bugrov, who gave his blessings to the turbines for the 2,100,000-kilowatt Kuibyshev Hydroelectric Station, each one of which needed 120 railroad cars to be shipped off. And, given good health, Bugrov will be around to wave goodby to the turbines for the Yangtse Project in China that is to have a capacity of 20,000,000 kilowatts, more than eight times that of Grand Coulee on the Columbia River in the United States.

It is men like Bugrov — calm, solid, conscious, proud — who come to my mind as I drive over the roads of the Soviet Union and see the Y-shaped masts that carry the endless high-tension cables and that are the true heraldry of socialism. Lenin once remarked that Soviet power plus electrification equaled socialism. Lenin's equation has more than one meaning. It means that electrification under Soviet power has a quality different from electrification anywhere else and that the men working on it create not only electricity. And it also means that you can't have socialism without electrification.

That's why each added kilowatt of power capacity under socialism means not just more steel, more light, more transport, more sputniks; it means a guarantee of the future of mankind.

Have a look at Professor Popkov's map.

It's a huge map, covering almost the entire wall behind his desk, and the Professor, who is a rangy, broad-shouldered, young-looking man, is dwarfed by it. The map, blue stars and red stars and green,

lines stretching from the Amur to the Donets, from Bratsk on the Angara to Sochi on the Black Sea, is past and present and future.

"This is going to be your grid?" I inquired, because here I was at the Academy of Sciences' Institute for Power Research, and Professor Valery Popkov was its head and if anyone could tell me about those Y-shaped masts and the double character of electric power, he was the man.

The Professor frowned a little.

"Grid?" he said. "The word grid doesn't quite seem to encompass the size of the project we plan. Perhaps we might call it a United Power System — yes, that's more like it."

"You haven't got it, though."

"No. But we will build it."

I glanced over the Professor's head at the map. There were four galaxies of stars, each star a larger power station, with lines linking stars and galaxies. The points of density were in the Moscow-Kuibyshev area, around the Donets Basin and Stalingrad, in the Urals, and then east, where the rivers of Siberia swell.

"There are power grids in other countries, too," he said. "But we don't know of any country where as much power is transmitted over as long distances as in ours. Technically the United States might be able to do it. But they don't. Their electric power is private property, each company its own kingdom. Our electricity is socialist."

I remembered the fight over the Tennessee valley where the U.S. Government built the dams and the generators. I could hear the echo of the sonorous voice of Franklin Delano Roosevelt saying that all this belonged to the people of the United States. But the power companies ganged up on the people, and in the end the inexpensive power of the Government's Tennessee Valley Authority had to be paid for by the people at a higher rate, approaching the exorbitant rates charged by the private companies.

"It's not easy," said Professor Popkov, "to master the problems that are connected with those super-long-distance transmission lines. There's loss of power along the way, there's the question of stability, the need of split-second coordination of huge grids lying thousands of miles apart. I'll take you upstairs later and show you the Siberia-Urals line."

*"Upstairs?"* I asked.

"Upstairs," he nodded. "We have it set up in a room there."

"I always liked toys," I said. "Toy trains, toy cranes, toy transmission lines. A case of retarded development, I suppose."

"It isn't a toy," he said. "We're working with it."

"Oh," I said, "in that room. How long did you say the line was?"

"Two to two and a half thousand kilometers, depending on its final route. Kuibyshev-Moscow is nine hundred kilometers; that's finished. We're constructing Stalingrad-Moscow, Kuibyshev-Urals. These are all AC current, with tensions of 400,000 and 500,000 volts. The Urals-Bratsk line is projected for 600,000 to 700,000 volts. But we're also experimenting with DC, and we're going to try it out on the Stalingrad-Donbas line. By the time we get through we'll have fifteen to twenty times the high tension linage we have now."

"Pretty expensive, those lines, aren't they?" I put in, because my head had begun to swim in a confusion of voltage and kilometers and alternating and direct current.

"Very," he said. "Moscow-Kuibyshev cost 300,000 rubles per kilometer, figuring in transformers and other items. But it pays. Moscow-Kuibyshev should pay for itself in six to eight years; Kuibyshev-Urals will be pure profit after three years."

"How? You need transmission lines to transmit your current to the consumer, the same as you need telephone wire to transmit your call. Neither strikes me as a money-saver."

"High-tension lines are expensive. But power stations with their generators and their boilers and what-have-you cost even more. If at a split second's notice we can transmit huge blocks of power from the Donbas to the Urals and vice versa, from Stalingrad to Kuibyshev and from Bratsk to Moscow, whenever and wherever the power is needed, then we don't have to build so many reserve power-producing installations as we otherwise would. Because you can't store power. You have to be able to switch on additional capacity or take it from somewhere else – if you can get it. And don't you think it's more economical to transport your energy in the form of current than in the form of coal?"

He spread his arms from the Volga to the Angara. "Why, we can lick the nightmare problem of the power engineer: the peak hour. When the lights are switched on in Irkutsk, Moscow still has five hours of sun. We can work out an electric power regimen from Brest to Vladivostok saving billions of rubles. We can balance steam power and hydroelectric power and work in the atomic power plants as they're being built; we can balance the hours and the seasons and create a two-continent system working smoothly and evenly and economically and –" he smiled, "automatically."

I did see the Bratsk-Urals high-tension long-distance transmission line.

It stood on three shelves, each about five feet in length, and was in the charge of Candidate Scientist Liebkind, who had been trying it out for a year and thought he would have all the kinks out of it in another year. Scientifically they call this thing a voltage regulation reactor, and it looks as if mother's pickle jars in the cupboard at home had been wired and booby-trapped. Each pickle jar is, I am told, an induction coil and takes the place of one hundred kilometers of high-tension line, with a cigar-like attachment next to each pickle jar furnishing the resistance the line would offer.

Candidate Scientist Liebkind is a serious person whose infrequent smile collapses quickly into concentrated intentness. I doubt that he is conscious of anything ludicrous about this Liliputian world of his in which the distances of a continent are squeezed into a few shelves, in which a flimsy roll doubles for hundreds of steel masts with miles of cable swinging between them.

It takes a bit of contact with these power engineers, computing-machine experts, atom splitters, space explorers, and what-have-you to get the feeling that Liebkind might be right and that our ordinary conceptions of large and small are actually outdated and no longer suffice. On the one hand we deal with phenomena so huge that we can comprehend and handle them only by reducing them to the size of laboratory models; on the other we're beginning to look into processes which take place within the particles of particles and which we can grasp only through their reflection in some man-sized instrument. The infinitesimally small and the infinitely large touch upon one another somewhere: the everlasting nebulae millions of light years removed from our galactic system and the mesons of a nucleus that are born and die a million times while you read these last few words are somewhere related, and time itself loses the meaning by which you and I regulate our lives.

I had this same uncanny feeling in an ordinary room in Rostov-on-Don, in an ordinary office building on an ordinary street.

One wall in this room was taken up by a large panel on which ran the straight yellow lines with the neat angles and crossings that are so dear to the heart of the electrical engineer. Together with the tiny squares that lit up in yellow and orange and red, this was the diagram of the circuits of the Rostov Power Grid which, joined to Dnieper-Energo, Donbas, and Stalingrad-Power, forms the Unified Southern Power System of the USSR. At the right end of the panel, lines and lamps condensed to show a distinct block: Tsimlianskaya Hydroelectric Station.

A desk stood parallel to the panel so that the man behind it could keep in view the scales and dials on the desk and the little lamps on the panel. The man behind the desk was young and relaxed; he had before him a sheet marked with curves that told him when he had to send power to the Donbas and when he would receive power from Stalingrad, that day. Another sheet gave him the regimen of his own four power stations — three steam, one hydro.

"Zdrazd', Mikhail Vas'ich," he greeted, swallowing, as the Russians love to do, three-quarters of his syllables. The white-haired, well-groomed man thus welcomed was the chief engineer of the Rostov Power Authority. A former oiler on a Don River steamboat, Mikhail Vasilievich Koslov now was master of 700,000 kilowatt of power capacity, and one of the builders of the automatic control system which, without a man's voice, without a man's touch, links Tsimlianskaya Hydro-electric Station to this room in this Rostov office building.

The young man motioned me to his desk and stepped back invitingly.

"D'you want to try it?" he asked.

I was not quite certain that I should. My experiences with things electric at home always end with me getting a shock and with the house being plunged in darkness. I didn't want to jinx the Soviet Union's Unified Southern Power System.

"It's all right," Koslov assured. "I told you we automated this ourselves, so we know it works."

He *had* told me; I was coming to realize how great a hold this automation business had taken all over the Soviet country. It was being worked on in many institutions and many industries, "at the base," as they put it, and not just in a few institutes of the Academy of Sciences.

I pressed a little pink thing that looked more like a piece of peppermint candy than a power switch.

Nothing happened.

No. Something did! On one of the gauges on the desk a thin indicator began to tremble. It fell lower, lower — from 160 to 140 to 120 — then it held.

"What does it mean?" I asked, relieved that no more than a change on a scale had occurred.

The young man, who was duty engineer for the day, said, "You have just shut off one of the generators of Tsimlianskaya. The station is furnishing 40,000 kilowatts less power."

The little pink switch that I had so recklessly flicked suddenly appeared awesome.

"Maybe we'd better put that power on again?" I suggested.

"Maybe we'd better," said the young man.

The dun-colored grasshopper of a plane had climbed to about eight hundred feet. There it leveled off, beneath it the sluggish tributaries of the river Don and the steppes that looked fresh and green with spring just begun. The steppe wind buffeted the plane, and the few passengers, facing one another from their bucket seats, laughed in the forced way of people unsure of their stomachs.

But the only one reaching for that paper bag was the engineer from the Rostov Power Authority who had been detailed to chaperon me to Tsimlianskaya – and he a former sailor in the Soviet merchant marine. The young girl sitting across the narrow aisle from me was snuggling up to her fiancé and saying with an honest joy that touched me, *"Nashe Tsimlya!"*

They were going home to Tsimlianskaya. Funny, being homesick for a place that has existed only six years. But first we were stopping at Konstantinovka, a shack in the middle of nowhere. The landing reminded me of coming down at the old Acapulco airport in Mexico. There, too, the plane had circled over the field until a peasant had chased a grazing burro off the strip; here it was a couple of cows whose quota of ruminating was upset by the landing.

Shortly before Tsimlianskaya the co-pilot waved me forward and let me have his seat for a minute or two, and it was a sight to make your heart jump: the brilliant southern sky, blue, with not a cloud on it, the glistening silver platter of the man-made sea, and the yellow sweep of the dam with the toy turrets of the power station.

There is some criticism now of the gingerbread figures atop industrial installations, but Tsimlianskaya dam and station and the Volga-Don Canal with its fifteen giant locks were built in that postwar period when heroic gesture and heroic symbol reflected a genuine wish to commemorate for times to come a heroism which had been genuine. Alexander Ilyich Soldatov, the chief of Tsimlianskaya station, said, pointing vaguely upward, "They won't build another station like that..." and it was hard to guess from his voice whether he regretted it or felt relieved.

As far as I'm concerned, I liked the memorial to the builders of dam and station – the Tomb of the Unknown Foreman, as Tsimlianskaya wits call it. It stands, neatly etched against the pastel sky, on a green knoll just at the entrance to the nine miles of dam. I think that people who in two and a half years built this dam and this power

station and a canal by which great ships can climb over a mountain have a right to build themselves a monument.

The part of the dam that holds the power station is made of solid ferroconcrete. "Do you get dizzy?" Soldatov asked. But he asked it too late — we were already crossing a kind of catwalk, to the left of us Tsimlianskaya Sea, nothing but glistening water held back by the enormous steel of the floodgates beneath us, to the right a concrete abyss with the Don trickling away at its bottom and an automobile road leading across.

I refused to give in to whatever it was that wanted to pull me down the steeply curved wall which in another two or three weeks would be washed by the waters of spring foaming through opened floodgates.

Soldatov waved toward a maze of pylons, insulators, and wiring at some distance. "Transformers!" he shouted back to me and then, his arms sweeping toward two chains of Y-shaped masts joining the horizon with his station, "High-tension lines — the one to Rostov, the other to Stalingrad!"

"Terrific," I said, glancing in the directions indicated, and then gluing my eyes to my feet again.

"This is really a small station, as our hydropower stations go," he explained. "Today we know we should have made it bigger. But at the time it was thought of as a by-product to the real project — the canal and the control of the Don, navigation, irrigation . . ."

"How much longer do we have to walk this tightrope?" I asked.

He waited for me. "Do you like to fish?" he said. "The fish come from downstream and want to get up to spawn, and down there where you're looking —"

"I'm *not* looking."

"That's where they gather and wait for the elevator to take them up and dump them into Tsimlianskaya Sea. Just lower a net from here and you'll get dozens. We make a very good fish soup in this region."

"*You* lower a net," I said. "The way I feel I would lower myself along with it."

"You're back on solid ground, man," Soldatov replied. "We crossed the gates in three minutes and a half. Now we'll have a look at the elevator."

The elevator was in a tower of its own. It consisted of a big metal basket that came soughing from the depths; but it held only a few passengers. The tourist season for fishes had not yet begun, Soldatov informed me, and besides they preferred traveling at night.

If I could come around any night two weeks from now I'd really see some fish!

"Is this a sturgeon?" I asked, pointing at a silvery shape that was wriggling through into the sea.

Soldatov shook his head. It seemed that every conceivable kind of fish rides up and down this elevator without fuss or trouble, except the sturgeon which lays its eggs in the form of black caviar and for whose sake the elevators had mainly been built. The sturgeon doesn't like riding in elevators, even though the professors who specialize in fish travel have tried to lure it into doing so by every means, including electric shock treatment. A few broken cables dangling into the Don at the foot of the power station are the last remnant of the sad experiment. Now the sturgeon's fry has to be shipped in containers, and the price of caviar has gone up.

There isn't a soul in sight in the generator hall. Like smooth gray domes, the tops of the generators protrude above the floor, implying the hugeness of the unseen turbines rotating below and the force of the water hitting their blades. Nor does the high, windowless wall facing you betray by even a tremble that today it is straining to hold back a sea containing twenty billion cubic meters of water.

Everything here is automatic. Within a metal-covered column next to each generator a small gadget gyrates as the turbine revolves, the shining weights at its end rising or falling with the number of turns. This fragile toy is no taller than my fountain pen. Through a hydraulic mechanism it controls a steel lever the size of a sturdy tree trunk. The lever, at the foot of the generator in the cool depths below the level of the river Don, regulates the flow of water into the blades of the turbine and thus determines the frequency of its revolutions.

Finally a man appears. He wears a worker's peaked blue cap, has a worker's face and a worker's hands, but for the rest he is dressed in a dark business suit with a white shirt open at the collar. He is the foreman of the generator room. He has just come through on one of his rounds of inspection, and now he is joined by a second man, the worker on duty, who had been hidden at his writing desk in a niche of the window wall.

The foreman, lighting a cigarette and carefully putting the burnt match back into his match box, explains that the worker is studying to become an engineer. In fact, not just one but two of the four men that run these generators in shifts of six hours each are taking college courses. Yes; the more you know the better you work; the better you work the more you produce; the more you produce the better

you live. Last year, Tsimlianskaya produced one billion kilowatt-hours instead of the five hundred million planned, and they did it with less than half the man-hours they used in 1954.

"How did you do that?"

He looks at me, flicks the ashes of his cigarette into his cupped left hand, and says, "By thinking about our work; raising the level of the sea by another two and a half feet; automation."

Back in Moscow, at Professor Popkov's Institute for Power Research, I had been told that per capita production of electric power in the USSR is one-third that of the USA. But the USSR has tripled its power production every ten years while the USA only doubled theirs, so that by 1975 the Soviets ought to have closed the gap.

Down in the generator hall at Tsimlianskaya, looking at the foreman who used his hand as an ashtray so as not to dirty his place of work, and at the worker who held the text book he was studying, his left index finger pressed between the pages he wanted to go back to, I thought that in this struggle for power the Soviet Union might catch up even before that time.

And it will, because a decisively new and revolutionary factor has entered energy production. Professor Popkov's estimate was based on power sources which by now have become conventional: steam, water, natural gas, oil, and controlled uranium fission. But science is working on wresting from the nuclei of matter a thousand times the energies of atomic fission. Science is proposing to re-create on earth, under the control of man, the processes taking place in sun and stars.

Utopia?

Hydrogen fusion is no utopia. Capable of wiping out large parts of mankind if uncontrolled and in the hands of the wrong sort of people, it can lift mankind to unheard-of levels of abundance and culture if we manage to control it physically, technically, and politically.

It seems safe to say that the new sources of energy, once opened, will be so ample and their expense per kilowatt-hour so negligible that the entire picture of the struggle for electric power is bound to change.

There will be a day long before 1975, I guess, when we shall look back on past efforts to wring power from nature with the same deep thrill and the same nostalgic smile we have for those pioneers who wrote Lenin to come to Kashino where electric light would be switched on for the first time in the village's history.

## Dubna Opens the Cosmic Age

The trees, pine and birch, were old, the roadways new. Everything else in this town was new: the buff-painted buildings, the street lamps, the signs; and more was under construction — laboratories, an institution where theoreticians could just sit and think, apartment houses, community services.

A strange town with no industry but science, using invisible particles as raw material. A strange town where a dozen languages are spoken within one block and where the bus conductor calls, "Nuclear Problems!" to announce his next stop. A strange town — a hunk of future transplanted into the present.

It was here and within view of the great circular temple holding the world's one and only ten-billion-electron-volt synchrophasotron that Professor Valentin Afanasyevich Petuchov casually stated, "You know, the so-called atomic age will be the shortest era mankind ever knew; I give it fifty years, no more.

"Oh, no," Professor Petuchov laughed. "I didn't say it'll end by us blowing ourselves to hell. I meant the splitting of the atom, as we knew it, will be passé. But what we're now working on — this will last. This will be good for thousands of years . . ."

I asked Professor Petuchov what he would suggest this new age be called. He had no name handy.

"The cosmic age, maybe?" I prodded.

He agreed that it was as good a name as any — provisionally, that is: until the men who would people that age had gotten together on some more permanent label.

What were they working on at Dubna?

There is no secret about this town which lies at the precise junction of the Moskva Canal and the Volga River. There could be no secret because scientists and research workers from a dozen countries, several capitalist as well as socialist, work here for varying lengths of time; visitors from dozens of countries come here; and the work itself is described in hundreds of scientific papers which are sent to scientists all over the world and printed in journals of capitalist and socialist countries.

As Venedikt Petrovich Dzhelepov, Professor of Physics and head of Dubna's First Laboratory for Nuclear Problems, told me, "Before technical conditions can be created for a possible military use of our research, the world will have become very different." And after a thoughtful pause he added, "The period, by the way, until such

change comes about won't be long compared with previous historical epochs."

At Dubna they do what the Germans somewhat ponderously call *Grundlagenforschung*. They're trying to find out what keeps the nucleus from flying apart and what happens when you make it fly apart. They accelerate particles to speeds six per cent below that of light. They play with star dust. At Dubna they're after the law of all matter, after a system that will do for the strange microworld in which things are both wave and corpuscular what Mendeleyev's system of elements did for the world of the atom.

The story does not start in Dubna. It starts in the outer reaches of our galaxy or perhaps farther off, in other galaxies, where a star was born emitting in the process of its birth, as some people think, the cosmic rays which, at the precise second of your reading this, hit our globe. The story then takes us to the back yard of the Physics Institute of the Soviet Academy of Sciences on Lenin Prospect in Moscow. There, in a small, rather ramshackle laboratory, among his Wilson chambers and his tin trays filled with argon-loaded vacuum tubes, sits Sergey Ivanovich Nikolsky, mild-mannered and patient, catching these rays, counting them, measuring them, photographing their effect, even showing them to you on his oscillograph in the event a nice fat one hits through the laboratory roof.

Candidate of Science Nikolsky can explain to you what cosmic rays are. In most cases they are simple, everyday nuclei of hydrogen, which science has christened protons, or helium nuclei that go under the name of alpha particles. But these protons and alpha particles coming from outer space differ from their cousins on earth by their extremely high energy and speed. Nobody has established as yet any upper limit to the strength of these space travelers; there were blockbusters among them with energies of a thousand trillion or $10^{16}$ electron volts. No wonder that traces of the effect of cosmic rays have been found deep under water and in coal mines.

Because of their tremendous energy something happens when cosmic rays hit the nuclei of our earthly atoms. The earthly nucleus, under the terrific impact of the collision with the visitor from space, flies apart; the forces that held it together are broken, and there's a shower of particles — entirely new particles, entirely different in character and mass from the parent nucleus. These particles now begin a hectic but extremely brief life of their own. Hardly born, they die, and in dying change again into other particles. A pi meson may turn into a mu meson, the mu meson into a neutrino or perhaps into an electron. A pi meson may also decide to become a gamma ray,

which is just a pseudonym for X ray. Until now, twenty-six different particles are known to have come out of the old nucleus, with a good likelihood that we have not yet seen the end of it.

It is as if the high-powered guest from cosmos entirely upset the host he dropped in on, dismembering him and his family and scattering the parts to the winds. But the scientist observing the process gets a sudden glimpse into the real make-up of the nucleus that was hit, a glimpse into the make-up of the matter we live in and are made of.

But how often does it happen that the guests from cosmos penetrate within the scope of the scientists' instruments? Most cosmic rays spend all of their force in the outer reaches of the atmosphere. And if the lucky scientist finally gets hold of a cosmic ray, he can neither control nor direct it as he wishes. At best, cosmic-ray catching is a hit-and-miss game. That's why nulear physicists long ago started to dream of homemade cosmic rays produced down here on earth.

Among the men mulling over the problem was a former electrician's helper who had become laboratory assistant in the Soviet All-Union Research Institute on Electricity and who was studying physics on the side. If you took a proton, he thought, and accelerated it sufficiently, couldn't it be made to do the job of the cosmic ray?

Working in daytime, studying evenings, the young man did extra thinking at night. And he actually invented a particle accelerator that did the job, only to discover that someone else in some other country had already invented the identical machine.

The young man's name was Veksler.

I want to tell the Veksler story because in him I see personified not just Dubna but the driving force in Soviet physics.

Yoffe was tradition, the unbroken line that leads from Galileo to the builders of the sputniks. But Veksler is the product of the revolution.

He denies having been a *Bezprizhornik*, one of those tough kids bobbing cork-like on the waves of the revolution; outcast, starving, stealing, knifing; thoroughgoing cynics at age ten, running from the newly formed militia until, finally, they were caught and re-educated by some incredibly patient, incredibly wise Makarenko.

Questioned, however, Professor Veksler reluctantly admits that he was orphaned when he was seven. His father fell in the first year of the first World War, and his mother remarried soon after. Comes the revolution, and in 1920 – the boy has just turned thirteen – he is taken into an orphanage. But it's a new kind of orphanage, a Children's Town, they call it; and to distinguish it from other children's towns it carries the proud name *Communist International.*

Professor Vladimir Josifovich Veksler is a small-boned man behind a very big desk in a large, sun-flooded room. The tapered fingers of his thin hands move slightly. "We had a club," he says, "the Young Physicists Circle, with an instructor who knew how to inspire boys of that age . . ."

But it wasn't only physics that influenced the idea world of the youth. Those were hard times, filled with a struggle that demanded decisions early in life. The boy joined the Young Communist League, and not just for form's sake and because the membership book might smooth your way. Membership meant that you worked harder than the others and sacrificed more and set an example in everything you did.

"I was an active member!" The stooped shoulders straighten and the benign eyes light up with pride. "So the organization sent me to the Sverdlov Textile Mills in Moscow. That was a run-down plant that once belonged to a German capitalist. Huebner was his name. I was to help rehabilitate it."

From then on the Veksler story is that of literally millions of Soviet men and women, of the whole generation which today mans the executive positions in government and industry, leads scientific progress, and steers toward the dawn of communist society. It is a story of back-breaking work; of trying to meet the most basic needs of life while absorbing the techniques of the future; of eight hours at the machine and eight hours poring over books; of evening high school, college extension courses, examinations; of growing in stature to meet the demands made on you; of never stopping your studies, in war or peace.

The second – and this time unrivaled – product of the young scientist's searching mind was something called "proportional counter," a gadget designed to help establish the character and quality of cosmic rays. It also helped to bring the laboratory assistant at the Research Institute on Electricity to the attention of Academician Vavilov, who called him to the Academy's Institute of Physics.

This was the period when nuclear research everywhere began to shed its swaddling clothes. Skobelzyn came from Leningrad to take over the Physics Institute and gathered there a team of men whose fame, meanwhile, has grown worldwide: Tamm, Mandelstam, Cherenkov, I. M. Frank, and Veksler. Veksler now pursued in earnest his home-made cosmic rays.

The idea of accelerating particles was not new. In several countries construction on betatrons and cyclotrons had begun. Lawrence in the USA forced particles into a spiral, whipping them on to ever greater

speeds with each round up to an energy of 20,000,000 electron volts.

But there it stopped.

The problem that stymied the would-be producers of cosmic rays had been formulated by Einstein, and it read: $E=mc^2$, or energy equals mass times the square of the velocity of light. Since the velocity of light as well as its square are necessarily constant, the mass of a subject must grow as its energy grows. Ordinarily we don't notice such things because the energies with which we deal in daily life do not perceptibly change the mass of the things we deal with. The difference between the mass of a car moving at ten miles an hour and the mass of the same car moving at one hundred miles an hour is too small to be measured. But the identical car moving at 20,000,000 miles per hour would give an entirely different picture.

If we could telescope the process, it would be as if you started your drive in a small four-seater coupe which, by the time you got up good speed on the road, suddenly grew into a ten-ton truck. Naturally, your engine, the engine of the small four-seater, can't pull that truck. Precisely this is what happened to the particle in the old-type accelerator. It grew too heavy for further acceleration.

What Veksler did was to increase the strength of the engine as his vehicle became enlarged with the increased speed. As the particles were whirled around in the synchrotron, gaining simultaneously in speed and in mass, Veksler increased both the strength of the magnetic field that keeps them on their circular course and the frequency of the electric impulses that push them forward.

This is not the way Professor Veksler explained it to me. In speaking of himself and his life he had been hesitant, searching for words, obviously uncomfortable about relating personal matters; he became enthusiastic the moment talk turned upon his work, physics, and upon the process enabling science to accelerate particles to high energies and to a speed closely approaching that of light – the process to which Veksler gave the name "autophasing." He jumped up and led me to the blackboard. And as his hand flew over the blackboard, covering it with equation after equation, as he explained what he was diagraming, his personality expanded until he seemed to fill the whole of that large room.

"You understand, don't you?" he asked when he was through.

"Yes . . ."

Now I was hesitant. My mind was reeling, but I couldn't admit that he had escaped from me into a world of symbols, signs, and calculations into which I could not follow him.

"Professor Veksler," I said after a while, "how long did it take you to find the principle of autophasing?"

"I thought about it for years. But the essentials of the solution came to me in a single night."

He published this solution in 1944. Not quite a year later, and independently of him, the American MacMillan came out with practically the same idea. The quirk of fate so frequent in science had happened again; again the same invention had been made twice. But this time the priority was Veksler's.

Was it more than coincidence? Was it symbolic?

Perhaps. Symbolic, perhaps, for the growth of capability, scientific and industrial, of the first socialist country on earth.

In talking about that, Professor Veksler said simply, "I wish you'd compare the state of science in the United States and England on the one hand and the Soviet Union on the other, fifteen years ago and today."

He toyed with a large manila envelope on his desk. I could see the American stamps on it and read the sender's name: Columbia University, New York.

"We exchange preprints," he said. "This particular letter asks us to carry through an experiment for them on our synchrophasotron."

"Will you do it?"

"Why not?"

He smiled.

"They're ahead of us," he went on, "in some fields. In others, let's say sputniks, we're ahead. But the rate of development! . . . The rate of development is in our favor. That's an objective fact. Even if the United States government poured many more millions of dollars into research, socialist science is bound to surpass the progress of science in capitalist countries. Money, you see, is important — but it doesn't decide everything. People decide, cadres. And the USSR has inexhaustible sources of scientific talent."

He fell silent. The fire of the old Komsomol member that had broken through receded under the ashes of scientific detachment.

"You yourself, Professor," I said, "seem to be an example of the development of scientific talent under socialism . . ."

"Example?" he said. "I'm not an exception. Which is just the point."

The circular temple of science erected at the town of Dubna contains no image of anyone, God or mortal. In its precise center, under the cupola, stands a semicircular altar. But no sacrifices are

offered here, no incense burned, no candles lit. Instead, the altar holds hundreds of gauges, scales, knobs, switches: control mechanism for the magic that man is to perform here. Above the altar hangs a lamp. Now its light is green: you're all right, you may stay. When it turns yellow, watch out. When it flashes to red, flee! The red light means that everything about you breathes the invisible pest: radioactivity!

The holiest of holies in the temple's center is surrounded by some two hundred yards of circular race track. However, no horses run here, nor dogs nor any other animal ever cheered on by man. This track is doubly walled and airtight, a vacuum kept empty by the constant suction of fifty-six big pumps. The track is one huge electromagnetic field, reaching a maximum strength of 13,500 gauss; the earth's magnetic field, which makes all the needles of all our compasses dance, has a measly 2.3 gauss.

The race that is run on this track takes place in deadly silence. It lasts three and a third seconds, and in these three and a third seconds its tiny participants, the protons, travel the course four and a half million times, covering two and a half times the distance between earth and moon, and achieving a top speed of 282,000 kilometers per second. It may take a good athlete about twenty-five seconds to cover this track; the proton, endowed at the end of its race with an energy of ten billion electron volts, completes the course in less than a millionth of a second.

At this speed and with this energy it hits its target. A veritable cosmic ray, but man-made, it hits the nucleus of whatever atom the scientists, safely located in some distant building, have decided to submit to this treatment. Thus protected from the deadly effects of atomic radiation, the scientists receive on their instruments the indications of the presence of the particles and the presence of the forces that go to make up the nuclei of matter.

The question now is in order: What is the purpose of all this? Toward what end the giant apparatus which cost millions of rubles? The intensive effort of thousands of people — workers, engineers, scientists? For what use these mesons, neutrinos, positrons?

I asked this of more than one Soviet physicist. The usual answer was a shrug of the shoulder. There seems to be no immediate practical purpose to any of it.

But they will quote the considered opinion of Professor Blokhintsev, chief of the entire Dubna project: that never in the history of science have the physicists returned empty-handed from their search along new roads.

This is true enough. When at the beginning of the nineteenth century scientists deflected the needle of the compass by means of an artificially created magnetic field, could they foresee that their research would result in the electric motor? When in the early part of the twentieth century scientists bombarded uranium nuclei with neutrons, could they foresee that their experiments would bring about atomic power stations, atom-powered icebreakers, locomotives, trucks, and, such is the dialectics of our time, the atom bomb?

Professor Veksler said, "We want to *know*. We want to learn the nature of the elementary particles. We want to explore the structure of matter. We have already established that all these particles are related to one another and that we can produce one out of the other, so that the conclusion is permissible that the entire universe is actually one unity, one unified whole."

This borders on philosophy. Indeed, scratch a physicist deeply enough and you'll find a philosopher. But let's hold philosophizing for the moment; let us, instead, speculate on what might result once the physicists get to the bottom of what makes the universe tick, once they learn the laws of the forces that hold together the particles of the nuclei of the atom, once they are able to change and to utilize these particles.

This speculation, and it is not far-fetched, requires a return to Einstein's formula: energy equals mass times the square of the velocity of light. This formula means that mass is a quality of energy and that a very little bit of mass represents a tremendous amount of energy, provided you can transform your mass of particles into another form of energy. One gram of mass, for instance, equals 25,000,000 kilowatt-hours of electricity. That's why a fistful of uranium can make so big a bang.

Contrary to the layman's belief, it is by no means the entire fistful of uranium that goes up in energy. Only a tiny fraction of its mass destroyed Hiroshima; only a tiny fraction of its mass, in the hands of wiser people, heats the boilers of atomic power stations.

What actually happens? Under bombardment by neutrons, the nucleus of the atom of element uranium splits up. It splits up into the nuclei of two other elements, maybe of strontium and of xenon. But if you add the weight of a strontium nucleus to the weight of a nucleus of xenon, you discover that the total is just a bit less than the weight of your old uranium nucleus. Something has disappeared – not much, but it's definitely gone. And this something, this almost imperceptible difference in weight between uranium on the one hand and

strontium plus xenon on the other, this is what has been turned into a new form of energy.

Suppose, however, you could turn a larger part or perhaps the entire potential energy of the mass of the nucleus into heat, light, or another active form of energy – what then? What developed when that cosmic ray, star-born or man-made, hit a nucleus? The nucleus of hydrogen, called proton, flew apart; in its place there might turn up a meson, weighing only one ninth of the old proton; or maybe a few electrons remained, each weighing one two-thousandth of the proton that was annihilated. Or – dream of dreams! – *all* of the mass was transformed, and you have photons, pure light, pure radiation, the most active form of energy!

What boundless vistas!

Here are the sources of energy that may give man the speed of light and carry him to distant stars. Here are means of changing nature that will make today's Tsimlianskayas appear to future generations as the bronze tools of our forefathers appear to us. Here is a first dazzling glimpse into the age to come, the age being opened at Dubna, the Cosmic Age.

## Perspectives

"Nuclear physics," said Professor Petuchov, "once was *one* science.

"But the thirties, with fascism in Germany and the war coming ever closer, tore our science apart. The military began to be interested in nuclear research. Soviet scientists recognized the threat, too. You didn't have to be a great prophet to see the use atomic energy might be put to, in the wrong hands . . ."

Professor Petuchov looked up. "As you perhaps know, we solved the problem at almost the same time as the Americans."

"You did?" said I.

"It was two of my Soviet colleagues, Flerov and Petershak," said the Professor, "who discovered the spontaneous fission of uranium as far back as 1939."

We were both silent. I thought of two young people in New York, named Julius and Ethel Rosenberg, who as late as 1953 were judicially murdered on the allegation of the United States government that they had handed the A-bomb secret to the Russians.

"But the Americans threw the first atomic bomb," I said.

"That they did," he confirmed calmly.

"Well," I said after a moment's thought, "do you really mean

that the division in physics brought about two branches of this science: capitalist physics and socialist?"

"The facts of physics are the same everywhere. It all depends on who determines how they are to be applied."

"True," I said. "But sometimes I can't help feeling it might have been better to leave those nuclei as nature intended them — unsplit, unfused, untouched."

He shook his head. "The genie is out of the bottle, and no one can shove it back. We have to learn to live with it, to keep it from creating havoc, and to see that it serves us."

It sounded simple; but simple things are often the hardest to do. I told him of the group of atomic physicists I met at a dinner party in New York in 1946, and an unhappier and more conscience-stricken bunch of men I rarely ran into.

"Do you find us here unhappy or conscience-stricken?"

"No."

"Have you met Professor Pontecorvo?"

"Yes."

"Well, Professor Pontecorvo came to us from the West. He has worked in the United States and in Great Britain, as one of their leading atomic scientists. Did you find him unhappy here in his work?"

I smiled. Professor Bruno Pontecorvo had shown me all over the Dubna synchrocyclotron, the synchrophasotron's smaller, older brother. And I didn't need to close my eyes to visualize the narrow-faced, lively man crawling ahead of me through the innards of the huge electromagnet, pointing at the finish of the metal, at the blue and red paint, at the shape of the machine that resembled the bridge of a battle cruiser, and exclaiming, in his quick English tinged with an Italian accent, "Isn't this beee-autiful?" And again, in the synchrocyclotron's antechamber, where the thick wall is pierced by narrow apertures for the particles to stream out and where strange instruments and blocks of steel and shields of concrete are scattered about as if some young Gargantua had just stopped playing with them, "Isn't this beee-autiful?"

No, this was a happy man, happy in his work and its aspects, happy over this enormous machinery which he obviously considered his own, happy with his colleagues.

I had asked Professor Pontecorvo why he left the West where he had been as respected a scientist as any top man in the field of nuclear physics and where he probably enjoyed the bounty of capitalist comfort.

The youthful enthusiasm which until the moment of my question

had seemed to be the main feature in Pontecorvo's make-up suddenly vanished. His face looked drawn; you could detect something like hate on it.

"Ah, the dirty business!" he said. "The dirty business of misusing the results of our work! As if Hiroshima hadn't been dirty enough! But then it got dirtier day by day . . ."

And how dirty it is! And with what tragic consequences for the scientist of conscience!

On June 27, 1958, United Press reported from Chicago:

> "Mathematician Donald A. Flanders, aged 57, brother of Republican Senator Ralph E. Flanders from Vermont, was found dead today in his home, apparently from an overdose of sedatives. Mr. Flanders, whose mathematical genius helped develop the atomic bomb at Los Alamos, New Mexico, during the war, was director of the Applied Mathematics Division at Argonne National Laboratory, an Atomic Energy Commission facility southwest of Chicago. His wife, Sarah, found a one-page handwritten note, which said, in part: "I can't bear to go into the laboratory. There are too many decisions and I feel I am not capable of making them .... I am sorry for what I have done, but I had to do it."

Professor Petuchov resumed. "I don't think you'll find anyone here who feels about his work in nuclear physics the way our fellow scientists under capitalism are bound to feel when they take the trouble of looking into their own hearts. The reason, I think, is that the purposes of our scientific work here are in harmony with the purposes of our entire society."

"In other words," I said, "you don't seem to suffer here from the conflicts and contradictions that come about when one class of people creates all the values while another class appropriates them."

"We don't have capitalism," he confirmed.

"I'm a bit troubled," I said. "Obviously it would be desirable to bring about everywhere a state of affairs in which capitalists no longer can use the forces unleashed by the physicists to blackmail the nations and threaten them with new and more horrible Hiroshimas. But that will take time. Millions of people will have to have the right sort of experiences before they come to the right sort of conclusions."

"My colleagues over there," Professor Petuchov pointed toward the last red of the evening sky, "are doing their best to speed up the process."

I glanced at him. He didn't appear to be joking.

"The science of physics," he stated quietly, "will hasten the downfall of the capitalist system."

The science of physics, if we look back over the centuries, was always one of the prime movers of history. Its discoveries rang the death knell of the feudal world, and the rulers of that day knew very well why they had Giordano Bruno burned at the stake and why they forced Galileo to recant his findings under the threat of rack and torture.

The pattern of historic change is simple. The natural scientist conceives of new possibilities and proves them by observation and experiment. The technician applies the scientist's facts in practice and creates new forces of production. The new forces of production make the old relationships of production outdated and no longer workable; social revolution appears on the order of the day whether people are conscious of it or not.

Professor Petuchov put it succinctly. "Every discovery in our science points toward a time when all human needs can be filled as easily as you breathe the air about you. Energy out of air will be cheap and abundant. Can you monopolize air? And how can capitalism subsist when all the resources needed to sustain life will be—just air?"

Capitalism is being undermined by its own scientists. The paradox lies in the fact that many scientists have no notion that with every new process they discover they have dug another shovelful of earth for the grave of the system that commissioned them. Some of them do seem to have an inkling of this; I was told at Dubna of the famous Western physicist who at a recent scientific congress privately remarked that it would be better for the future stability of his government and others like it if they forbade by penalty of death any further research in nuclear physics, electronics, and automation.

But even if they wanted to, the capitalists could not repeat the medieval attempt to hold back the new time by muzzling scientists. In one-third of the world science is unfettered, and it is this competition which forces the capitalist system to pay for the rope by which it will be hung.

Nor is this a matter of an economy upset and thrown for a loss by new resources and new techniques. Equally important, perhaps more so, are the human factors involved. And though the majority of Western scientists and thinkers may be unclear about what history holds in store, there is no denying the deep, not to say tragic, sense of discomfort and fear that has taken hold of Western minds in the presence of the new forces.

No less a man than Professor Norbert Wiener, the coiner of the word *cybernetics* for the new science of self-governing and thinking machines, wrote in his book of the same title, ". . . taking the second

industrial revolution as accomplished, the average human being of mediocre attainments or less has nothing to sell that is worth anyone's money to buy . . ." Here is the picture in a nutshell. What Wiener describes in dry words is a world in which a few highly specialized men with a lot of highly complicated machines produce everything society can possibly consume, while the rest of the people, who used to sell their hands because they had nothing else to sell, cannot sell even these because hands no longer are needed.

What Western thinkers fear is that *man* may become redundant: a society choking to death in its own abundance; people living at sub-marginal levels in the midst of plenty; space flights, transistors, nuclear power on the one hand and, on the other, "average human beings of mediocre attainments" digging through garbage cans.

How much more optimistic, how much more certain of himself and of the society in which he lives, was Professor Petuchov at Dubna, who concluded his remarks to me by saying, "Once human needs can be filled as easily as you breathe your air man finally will be able to concentrate on his *real* purpose in life, on *really* living. We shall reach this state. Mankind is marching toward it."

Norbert Wiener, too, ultimately gets out of the doldrums. Though by no means a Marxist, he demands as an alternative to the cruel waste of men who have "nothing to sell that is worth anyone's money to buy . . . *a society based on human values other than buying and selling.*"

This, from the ideologist of cybernetics, is a very significant admission. And Wiener continues, "To arrive at this society we need a good deal of planning and a good deal of struggle which, if the best comes to the best, may be on the plane of ideas, and otherwise—who knows?"

I could name a few people who know: Marx was one of them. But for the moment I want to return to Professor Wiener's "average human beings of mediocre attainments," who are simply the great mass of working people, you and me. What is to become of us in that perhaps not so distant time when, according to Professor Petuchov, all the resources needed to sustain life will be—just air?

I presuppose, of course, that by that time we will have established everywhere the society based on human values other than buying and selling; a society in which the means of production and the distribution of what is produced are no longer monopolized by a few. What will we do then, we average human beings of mediocre attainments? Play checkers, like the men at the automatic line in the Lichatchov Automobile Plant? Plant flowers around our suburban homes? Go fishing?

Don't say that these are the things you have always wanted to do. Everybody likes to play games or lazy around in the garden or sit at the river. But all day long? Every day of the year? Every year of your life, while a kind-hearted society supplies you with the necessary food pills to keep your metabolism going?

You're not that kind of person. You don't like being a drone. You *want* to work! But what job can you get, you poor average human being of mediocre attainments?

The point which Professor Wiener forgets is that today, in the year 1959, you are average and your attainments mediocre because you have a 1959 brain which was trained ten or twenty or thirty years ago for purposes that could be foreseen at that time and for no more. Of course, there are people with more talent than others, and a lot depends on your chance in life. But I dare claim that the average human brain is one organ of the body that can be developed a lot further, and it won't take thousands of years to do it, it just takes schooling. I believe that the human brain has unlimited creative powers; I believe that man, the average man, will become master of the nucleus. I believe that intelligentsia comes from intelligence, which is something that can be awakened and furthered. And what I've seen in the Soviet Union, the people I've met, the talks I've had, have confirmed my belief.

The poor orphan who became the inventor of autophasing and head of the world's biggest particle accelerator, the printer's apprentice who became an engineer and chief of a hydroelectric station, the sons of peasants and laborers who today are members of the Academy of Sciences and lead the scientific progress of the world—they seem to be proof to me that not just the resources contained in the nuclei of matter are largely untapped but also the possibilities that are hidden in that gray stuff inside our skulls.

I don't worry about the average man being able to live up to the demands of the future. If man, who after all is nothing but a conglomeration of highly organized matter, has in the course of time become capable of unraveling the secrets of the very matter of which he is a part, I see no limits to what he can do.

I believe in the future. I believe in man. I believe in life.

If all these new developments in physics and engineering have so far-reaching and revolutionizing an effect on capitalist society, you can hardly expect that everything would go quite smoothly in the socialist world. The storm that throws up white-capped waves at one end of the lake will not leave its other end entirely unrippled.

The difference, to my mind, lies in this: the scientific discoveries and developments which in capitalism disturb the entire balance of the set-up and rapidly bring to a head insoluble contradictions, in socialism disturb only a few armchair theoreticians who have followed the same old rut for so long that they've forgotten the dialectical materialism they set out to find.

Nor is the dispute—which for a number of years has been going on under and sometimes above the surface of Soviet academic life, and which has aligned on the one side the physicists and on the other a number of professional philosophers—merely over the question of what comes first, the chicken or the egg. When you have to choose between the facts of life or theory, one of the two must be given priority.

As to which of the two, Professor Dzhelepov, head of Dubna's synchrocyclotron, told me of Lenin's saying that practice came before theory and that theory must be confirmed by practice. Any attempt to make practice confirm to theory, the Professor added, was scholasticism.

What happened in the dispute between the physicists and the philosophers was described by the rector of the University of Leningrad, the mathematician Professor Alexander Danilovich Alexandrov; "Some authors who called the theory of relativity idealistic, *although* it had been confirmed by experiment, placed opinion above practice; that is, they not only deviated from Marxism but even from Francis Bacon, who long before the dawn of modern science took a sharp stand against medieval servility toward authority and on behalf of experiment and practice as the basis for conclusions."

The physicists must have hit back pretty hard, because the same Alexandrov writes in the same article, published in the official *News of the Academy of Sciences of the USSR:* "In some cases the natural scientists argued against the dogmatism and the 'ignorance' of the philosophers on the same level that characterized the attacks of the philosophers who railed against the natural scientists for their philosophic 'distortions.' "

There is obviously more to it than a squabble between professors. Academician V.A. Fock in Leningrad, who combines in his own person the physicist and the philosopher, seemed to feel that a few more years of unchecked philosophic diatribe of this kind might have set back the progress of Soviet physics considerably, with political consequences which everybody can imagine for himself. Instead of getting theoretical help and support from the philosophers, Fock told me, the physicists were forced to dabble in philosophy as a sideline. Now, he said, a better and more penetrating discussion about the basic philosophical questions in physics is being prepared in the Soviet Union.

The problem lies in the recognition of where the new findings in nuclear physics belong in the conceptions of dialectical materialism. This, again, is not a matter of idle speculation. It would be awkward, to say the least, if the facts of modern physics were to contradict the one philosophy which has set out not just to interpret but to change the world.

It seems that some philosophers were discomfited by the new particles' outlandish behavior, as reported in the physicists' papers. These particles didn't follow any of the customary patterns. They weren't at all like the orderly stars by which you could set your watch and determine your ship's position. On the contrary, the particles, under identical circumstances and at the identical moment, did widely different things; and the physicists said that the most they could do was to establish a proportion of probability: how many particles would probably act thus, and how many so. On top of that, it was found in the mechanics of this microworld, in "quantum mechanics," that these particles were both corpuscular and a wave function, both body and motion, at one and the same time.

What to do with such particles—and such physicists!—which might spread their heresies outside physics, too, and upset the comfortable belief that *b* always must follow *a*?

In the journal *Successes of Soviet Physics* Academician Fock remarks dryly, "It was true that the experiences of daily life, in which mere possibility must be sharply distinguished from actual accomplishment, were against this belief; but these experiences were rejected as 'unscientific' . . ."

The second sin of the physicists was their blunt admission of the necessary interaction between the particles and the scientific instruments used to observe them. With objects as infinitesimal as the particles of a nucleus, the physicists said, a new element of relativity—relativity with respect to the means of observation—had to be introduced.

Well, said the opposition, if the thing exists only in relation to the instrument, maybe it doesn't exist objectively at all? Maybe physicists are trying to repeat the old stunt of the idealists; maybe, cloaking your hints in the abstract language of your formulas, you are trying to claim that a table is a table only because it is a table in your eyes but not a table as such, objectively, outside your instruments? Oh, horror! Oh, subjectivism!

The sputniks were more than a great victory of Soviet natural science over natural science in the West. They also cleared away a few cobwebs in the socialist world. For sputniks can be seen with the naked eye.

But what *is* the relationship of dialectical materialism to modern physics?

All Soviet scientists I spoke to agree that modern physics not only fits in with dialectical materialism but confirms it; that is, if you take dialectical materialism as a live thing, something dialectical in itself.

Professor Dzhelepov at Dubna pointed out to me that Lenin nearly fifty years ago said in his book *Materialism and Empiriocriticism* that "the electron is as inexhaustible as the atom, nature is infinite . . ." This was written at a time when protons and electrons were the only particles known to physicists. Professor Dzhelepov continued, "Only the thinking of materialist dialectics enabled Lenin to see that beyond electron and proton there must be other forces and other particles in the structure of the atom. . . ." The Professor then asked, "Do you know of any other kind of philosophy which would have the foresight to deal with the question in this way?"

But Lenin was a critical mind and a creative thinker, which seems to be what is very much needed today, too, in a time when every week opens new horizons, in a time of discoveries immeasurably greater than the discovery of America.

In the talk I had with Professor Alexandrov in his study at the University of Leningrad he told me, "The new in science forces us to do creative thinking; we can no longer get along by exclusively applying and repeating old formulas. Dialectical materialism is the very essence of all science; it is the essence of the development of man in human society. And within its framework we can and must understand the new theories of physics, the theories of relativity and of quantum mechanics . . ."

And Academician Fock, in his cluttered studio in an old tenement house of a Leningrad working-class district, stated, "Out of the theory of the atom we see arising questions of the greatest importance for dialectical materialism." Then he searched through piles of papers and came up with the English translation of an article of his recently published in the Soviet Union and abroad, and I read: "The solution of philosophical problems of natural science cannot be attained by choosing quotations from the classics but must be approached in a creative way. It is necessary to develop dialectical materialism itself. The ideas of atomic physics are really radically new and can in no case be set aside in an attempt to reduce the matter to those ideas about which we have ready opinions in the classics . . . He who in the name of materialism tries to negate new and to restore old ideas does a bad turn to materialism."

Unforgettable are the powerful head of the man, the searching, dark

eyes, the finely chiseled mouth, the slow, soft, groping way of speech, the hand holding out a hearing aid. The man, the crammed bookcases, the chairs ajumble around the large black table, the light falling obliquely on the writing desk, and the puttering of the old housekeeper sounding through the door gave an atmosphere all its own to what I read next: "Quantum mechanics found the solution of the contradictions between the wave aspect and the corpuscular aspect of the electron, between probability and causality, between quantum description of the atomic object and classical description of the instrument, and also between the properties of an individual object and their statistical manifestations . . ."

I looked up from the print, at the physicist-philosopher. What he had described was the great unity of the opposites, and I thought of Veksler in Dubna, who had spoken of all of nature being one.

"These achievements," I read on, "constitute a set of striking instances of dialectics as applied to natural sciences, and this remains true whether the dialectical methods were applied consciously or not."

"Professor Fock?"

The hearing aid crept closer.

"The other day," I said, "someone in Germany told me of Heisenberg's private comment that nuclear physics could be understood only if regarded dialectically."

I thought I caught something like a smile around the sensitive mouth. "Max Born," Fock said, "is also groping toward materialism. And personal conversations with Niels Bohr led me to the firm belief that in reality his position is much closer to a materialistic one than you would think from reading his scientific papers."

"There seems to be," I remarked, "a certain similarity between those great minds in Western physics and Molière's *Bourgeois Gentil'homme,* who discovers to his own surprise that all his life he's been talking prose."

This time the smile was unmistakable.

Of course they all talk prose. If nature itself is dialectics, natural science will obviously reflect the dialectics of nature. Nuclear physics not only fits in with dialectical materialism but will, as Professor Fock put it, "give a powerful stimulus to its development."

I believe he is right. It strikes me that Marxists cannot close their minds to new findings in science, indeed to any new value created by the brain of man. More: they ought to appropriate as theirs by right all that is new and promising and beautiful, because they are the leading force and advance guard of the new class and the oppressed peoples to whom the future belongs.

# THE DREAM, THE SEARCH

It would be foolish and a disservice to the cause of socialism if I reported that all of the Soviet Union was a gleaming, streamlined paradise on the threshold of the cosmic age, with electronics, automation, and atom power a part of everyday life. On the road to Dubna, near the modern locks of the Moskva Canal, lies the town of Dmitrov, looking for all the world as it must have looked a century ago, with its crooked wooden houses, its market square fringed by clapboard shacks from which the paint has peeled, its streets deeply rutted. The old is still very much around, and the new is born the hard way, always.

Nor shall I bother to elaborate on the many reasons that could be given for these contrasts: the wars that had to be fought, the backwardness of the country in which the Soviets had to start building, the insufficiencies of many people. I'll simply say: The cardinal fact is not that Dmitrov is next to Dubna, but that Dubna is next to Dmitrov. What will grow, and last, is not old Dmitrov but new Dubna. What will grow, and last, are the new people with their new attitudes.

As far as I can judge, the Soviet scientists, physicists especially, are marching prominently in the forefront of these new people. I have found combined in the Soviet scientists profound knowledge and ability in their fields, objective judgment of necessities and possibilities, and great political wisdom. And this applied whether the man I talked to was of worker or peasant origin, stemmed from old Russian intelligentsia families, or was, as happened too, the son of a tsarist officer. It seems that the life they led, the circumstances under which they worked, the struggles they no doubt had, and the efforts they exerted in common with their fellows have made them into a breed of man willing and able to help their country toward the great future they envisage for it and to help the world toward the peace it craves.

For peace is essential. The great work of the great minds of science can be turned into a catastrophe by small minds with a vision restricted to business interests. The conversion into energy of the relatively tiny mass freed by the fission of a uranium atom or the fusion of hydrogen atoms can obliterate a large part of the globe and maim whole future generations.

The question of war or peace came up in practically every conversation with Soviet scientists; and where it didn't crop up by itself I brought it up, because living as I do on the Berlin powder keg, in the split capital of a split country, I am inclined to be sensitive on that score.

Like physicists everywhere, the Soviet physicists know the earth-shaking power of the forces with which they work. None of those I talked

to had any illusions about the danger these forces represent in the hands of unregenerate Nazi generals and frustrated brink-of-war politicians.

For all that, the Soviet physicists definitely seem to believe in the likelihood of continued coexistence. I don't think they could work as calmly and confidently as they do, planning for decades to come, if they had too great a doubt of mankind's ability to bridle the bomb-rattlers.

Ever since Sputnik One, the public in the West has been asking and the press in the West has been puzzling over the same question: How did Soviet science catch up with American technique in so many fields and surpass it in others? Most editorial writers trying to furnish answers offered money as one reason and schools as the other.

No doubt both reasons apply. In Dubna I queried Professor Veksler on the financial angle of basic research in Soviet physics. He told me frankly, "I don't bother about money. I tell the Academy of Sciences what I think is needed, and if I convince the Academy, the money, the men, the machines, and the materials arrive. I know of no case in which an authoritative group of scientists approved a project and the government denied the funds for it."

Schooling, or what the Soviets call the creation of cadres, seems to be the more cogent reason. Soviet institutions graduate many more engineers and physicists than do American colleges and universities; yet the difference lies not only in numbers. School here is not like school there: the Soviet educational system differs from the American mainly in that it is socialist, doesn't make the youngster's training depend on Papa's income, and draws on the best talent of *all* strata of the population, *all* national groups, without discrimination. How much talent is lost to American science by the denial of equal educational opportunities to the Negro people? How many brains are wasted in the United States because highly gifted young men and women have to help support the family instead of being able to study?

In the Soviet Union democracy in education—genuine democracy, not just talk about it—has begun to pay off; and over the coming years the whole socialist third of the world will reap what the revolutionary generation of the Soviet Union sowed when it gave its schools preference over its stomachs.

But there is still more to it than money and schools. There are general attitudes which matter, the sort of values you stress. Differences in the economic and political system of countries are not limited to the realm of economy and politics; they enter everybody's life, making a person happy or unhappy, attracting or repelling him, molding his

mind and his heart. Professor Dzhelepov at Dubna, who appears to have a knack for sociology, put his finger on it when he said, "In socialist countries the results of the scientist's work go straight to the people; in capitalist countries they're bought by the capitalists. This makes for a psychological factor which under capitalism impedes, under socialism further the development of science."

It may not be as clear-cut as that always and everywhere and with every scientist. People are complicated, and a lot of motivation is hidden beneath the surface. After Professor Veksler had warmed up a bit, I dared ask him what made him work as hard as he did, what drove him to search further and further into that weird world of the particles. Was it curiosity? Or what?

He thought for a long time. Then he said, "I guess it's what makes the composer compose, the writer write—a desire to create, to create something new . . ."

And in that prerevolutionary tenement in Leningrad Academician Fock mused that he was always lured "by the possibility of creating a theory of which one may claim that it has a certain beauty . . ."

By that time I was no longer open-mouthed at the conception of beauty in physics. "Doesn't it ever happen, Professor," I asked, "that your search for beauty leads you to the wrong theory?"

"In physics," he answered, "a beautiful theory will correspond to nature and agree with experiment and will, at the same time, show that inner perfection . . ."

I was silent. He had touched on something very deep and very good in human nature, and he was probably correct as regards his science, too.

And then—the dream.

It took me a while to find out that this was the great open sesame to the heart of even the most reserved Soviet scientist; for it wasn't always easy to get them to talk. They were willing to speak of their work and the work of their institutes and their laboratories; but I wanted something more. I wanted the stuff that life is made of and countries grow by; I wanted their views and their feelings and their histories; I wanted their dreams.

There wasn't one among those to whom I talked who hadn't dreamed some part of the great dream. The most reluctant to speak, Professor Trapeznikov at the Institute of Telemechanics, said, "Dreams . . . Sure, what we do here borders on the fantastic. Isn't it a fantastic task for science to create systems which work without man and perform jobs that once required human effort, human thought? I find it inspiring to work on projects that will ease man's labor and make it more satisfactory. I see no limits to what can be done. In the not-so-distant future we

hope to have entire plants that are fully automated. They will embody the hopes and the dreams of the people who work in this institute."

Professor Zhusé, in Leningrad's Institute for Semiconductors, dreamed of a future in which, similar to Trapeznikov's automatic machines, semiconductor devices would lighten man's burden and free man for tasks which are worthy of him.

And the younger men and women to whom I spoke—students, research assistants, laboratory people; those working in teams and those striking out on projects of their own—I don't recall a single one who behaved as if he had gone into physics for the money in it or because it was a job and probably easier than working in a coal mine.

Natalya Yerichova, the molecule girl whom I had met in the shadow of the "Ural" computing machine, now said that she could have a better paying job—one had been offered her in the accounting department of some plant—but she couldn't live a routine life; in physics she discovered something new every day, and it was exciting.

Vladimir Alimovsky, a blond boy with a strangely weather-beaten face, expounded on happiness. His happiness lay, he said, in seeing to it that people got what they needed. He wanted an active part in the construction of that new society where people were happy. The people's happiness, he felt, consisted in their being enabled to engage in work that inspired and stimulated them.

Jurij Marosov, with his thin face and his shining eyes, had dreamed of building atom-powered steamships but had landed in the problems of luminescence; and Alfred Blashevich assured me that in the Soviet Union automation was introduced for the benefit of the people exclusively and that your social aims and purposes were the criterion of whatever you did in science, engineering, or economy.

Nikolay Karlov, with his live face, rather mature for his age, spoke of that scene in Tolstoy's *War and Peace* in which the Russian soldiers withdraw from Moscow, devoted to one cause, though only dimly aware of it. How much easier was the road for people, he said, who know what the cause is and who know what to do.

Vzeslav Patskevich, the young Byelorussian, confidently predicted a world of communism because, as he said, this was the only sort of world in which there could be no more wars; in which there would be enough of the goods of life for everybody and everybody could choose what he wanted to be and could realize his dream . . .

If I have seemed partial to these young people, it is because I share their dream—the great dream of mankind that might be so simply summed up with: *From each according to his ability, to each according to his need.*

# *A VISIT TO SOVIET SCIENCE*

## by STEFAN HEYM

Following the launching of the Soviet Sputniks, there came reams of discussion, polemic and "analysis" by western experts who, abetted by wire-service research offered dozens of explanations why peasants were first into space. Suddenly Americans were aware of the great universities and scientific centers in the Soviet Union where men and women carried on highly complex and sophisticated investigations of nature. We learned of new advances in chemistry, physics, medicine, engineering and education which resulted in the startling achievements of the Russians.

Now, for the first time we have an eye-witness survey of the men and machines that make Soviet science. Stefan Heym's *A Visit to Soviet Science* is a report on a series of fascinating visits he had with Soviet experts in a variety of scientific areas. Mr. Heym takes us to see the great institutes and laboratories where tiny transistorized computers handle the "homework" of hundreds of investigators in an instant. We hear about a giant billion electron volt proton accelerator that will probe the interior of the atom for the basis of matter and energy. A young scientific worker discusses plans for space exploration that sound to us like fantasy.

Significantly, Mr. Heym also reports on what motivates Soviet science. There is no talk of the Bomb in his book. Instead, we find a profound search for knowledge and a demand for a better life. Mr. Heym tells us of the dreams of the technicians and scientists—of a world that will be able to meet the needs of its population through the efficient use of its knowledge and its resources. These Soviet representatives of a new age of discovery are training their sights on the infinite and the infinitesimal in order to contribute to the growth of a socialist society.

Stefan Heym comes to his work with a fascinating background. Born in 1913, in Chemnitz, Germany, he was expelled from the local high-school for writing and publishing an anti-militarist poem. Later, he attended the University of Berlin and, in 1933, fled to Czechoslovakia on foot to avoid arrest by the Nazis. Eventually, he reached the University of Chicago, where he received an M.A., worked as a dishwasher, waiter, salesman, printer and finally as editor of an anti-Nazi weekly in New York. Among his writings that are well known to Americans are *Crusaders, Hostages, Of Smiling Peace, Eyes of Reason,* and *Goldsborough*. In 1951, Heym took up residence in the German Democratic Republic and last year made a first visit to the Soviet Union.

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